Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 652 – 656

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

Communication Resource Planning for Monitoring and Control Systems based on Distributed Virtual Instrumentation Networks

Traian Turc[a], Adrian Gligor[b,]*

[a,b] *"Petru Maior" University of Tirgu-Mures, 1 Nicolae Iorga st., Tirgu-Mures 540088, Romania*

Abstract

Distributed monitoring and control systems based on distributed virtual instrumentation networks consist of numerous components, ranging from field sensors to monitoring and control modules, which are potentially spread across a wide geographical area. This configuration requires a communication infrastructure to facilitate both physical and logical connectivity. In this paper, we tackle the challenge of planning communication resources that is in correlation with important topics such as: fast development, dependability and service availability.

Our discussions, conclusions and recommendations are based on an experimental platform developed in LabView. Our investigations pursue designing an optimal communication infrastructure and choosing the right communication bandwidth.

Peer-review under responsibility of the "Petru Maior" University of Tirgu Mures, Faculty of Engineering

Keywords: virtual instrumentation; SCADA; DCS; communication infrastructure; resource planning;

1. Introduction

Many technological processes are controlled by a significant number of functional parameters. Their efficiency is therefore highly reliant on the methodologies used for managing, monitoring, and controlling these parameters. Depending on the nature of the problem to be solved, basic instruments such as the ones provided by application development environments like SCADA (Supervisory Control and Data Acquisition) might suffice. However, real-

* Corresponding author. Tel.: +40 265 233 112; fax: +40 265 233 212.
E-mail address: traian.turc@yahoo.com, adrian.gligor@ing.upm.ro

Peer-review under responsibility of the "Petru Maior" University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.136

time requirements (such as dynamically changing the metric, time frame or display mode) can only be satisfied with a wide range of functionally complex instruments.

In order to accommodate for this complexity, the implementation of such systems must be versatile - basic hardware should support as much functionality as possible. This is the principle behind virtual instrumentation, which leverages commercially available technologies to provide a platform for sophisticated measurement systems. Virtual instrumentation allows multi-level solutions, which provide distributed access to functional parameters and fine-grained control over various layers of abstraction. This is particularly important in technological processes spread across wide geographical areas, where the functional parameters that control the distributed field sensors must be centralized.

One of the main challenges in implementing distributed virtual instrumentation solutions is to connect the physical field devices which collect the data to the virtual instrumentation modules. The performance of the network is highly dependent of the efficiency of the communication between its components. Fast and reliable communication comes at the expense of physical resources, and an optimal trade-off must be determined. Therefore, planning communication resources must be a priority in the design process. The purpose of his paper is to establish a methodology for solving the resource allocation problem in an optimal way.

Previous work employed virtual instrumentation in various applications, such as diagnosis and monitoring of industrial equipment [1], production, transport and distribution of electricity [2, 3, 4], environmental monitoring [5, 6] and industrial quality control [7]. Many of these publications have educational purposes, aiming to study the inner workings of various processes [2, 10, 11] or simply explore virtual instrumentation [8].

Resource planning and network design in the context of virtual instrumentation have been approached from various angles. For instance, Jamont et al. [9] propose a solution based on multi-agent self-organizing processes, which is applicable in the case of wireless or other complex networks. However, their design cannot handle static networks. In contrast, we propose a solution that is applicable for networks that are not dynamically reconfigurable. Beruti et al. [12] provide a performance evaluation of measurement data acquisition systems in a distributed computing environment that makes use of instrumentation. They assess how the response time is impacted by different communication mechanisms and networks under various loads.

Generally, previous work has provided guidelines on how to configure virtual instrument networks, but there is no specific research on how to determine the necessary communication bandwidth.

The remainder of this paper is structured in the following way: the Research Methodology section proposes an experimental platform and describes our investigations. The Discussions and Results section summarizes and interprets our results. Finally, the Conclusions section reiterates our findings

2. Research Methodology

In the context of environmental monitoring and control, one of the most popular graphical system design tools is LabView. Its popularity in the field of virtual instrumentation is the reason why we chose this tool to design our solution.

2.1. The Architecture of the Experimental Platform

Monitoring and control systems consist of numerous components, ranging from field sensors to monitoring and control modules, which are potentially spread across a wide geographical area. This configuration requires a communication infrastructure to facilitate both physical and logical connectivity. Planning communication resources is therefore a crucial part of designing the system. In order to estimate these values, we built an experimental platform, described below.

We developed this experimental platform in LabView 2010 and tested it in a laboratory equipped with communication bandwidth control. Figures 1 and 2 describe the architecture of our solution.

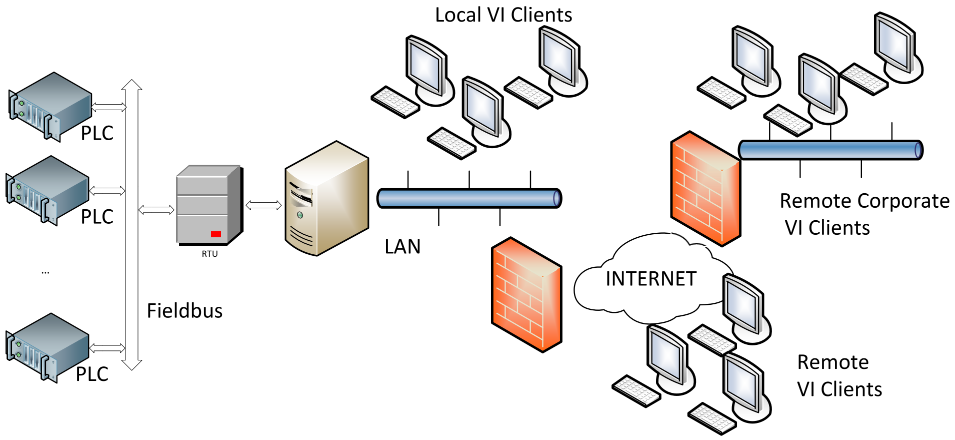

Fig. 1. The hardware structure of the experimental platform.

Our solution is structured on three levels. The first level consists of a) the data acquisition equipment, and b) the system to control the functional parameters. The second level is responsible for centralising the acquired data. Finally, the third level comprises modules for supervision and control, which make use of virtual instrumentation.

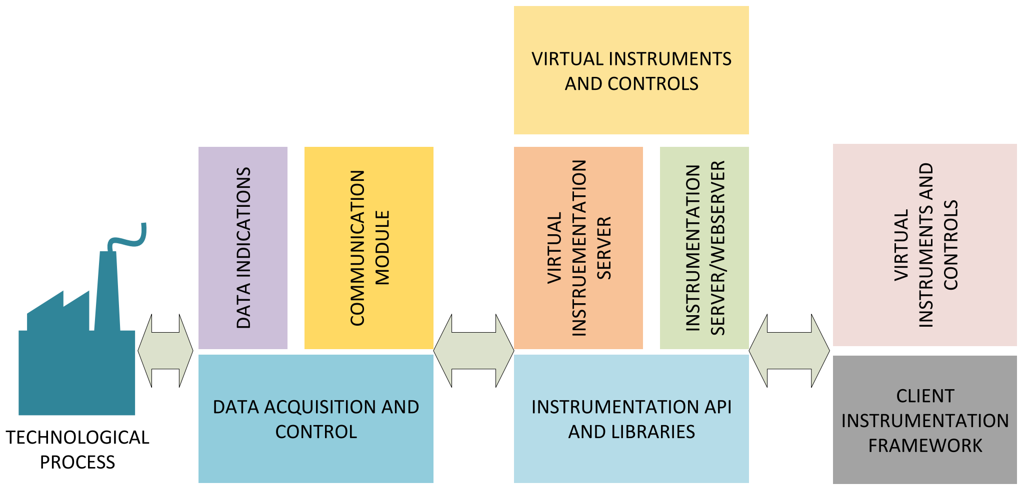

Fig. 2. The software architecture of the experimental platform.

The field devices are built as a series of PLC (Programmable Logical Controller), and encompass two main types of components: modules for local monitoring and diagnosis, and communication modules. The field sensors convert the analog signals that they sense into digital signals, and send them to an RTU (Remote Terminal Unit), over a Fieldbus network.

The data acquired is sent to the server, where it is processed, stored, and made available to both local and remote clients. The latter can be either stand-alone or web-based. The server and the clients were implemented in LabView 2010, using the native libraries. The TCP/IP communication and the other web components responsible for data acquisition and transfer were implemented using the LINX library.

We conducted our research by running multiple tests, varying the number of clients and the number of virtual instruments used by the clients.

3. Discussions and Results

Table 1 illustrates the results of our experimental measurements: for various numbers of clients n_c to the instrumentation server, we show the download and upload traffic loads.

Table 1. Number of clients versus download and upload traffic load.

No. of instrumentation clients (n_c)	Download traffic load [kbps]	Upload traffic load [kbps]
1	4.31	5.69
2	11.57	15.32
3	18.95	24.84
4	26.69	35.5
5	28.13	37.27
6	28.13	37.27
7	35.16	46.58
8	44.46	58.85
9	49.22	65.21
10	126.56	167.7

In order to establish the requirements for the data communication network for a virtual instrumentation application based on the above proposed model, we identified the following relationship, which expresses the minimum required real-time communication bandwidth as a function of the number of clients that will access the instrumentation server:

$$v = 0.7 \cdot n_c^3 - 9.9 \cdot n_c^2 + 45 \cdot n_c - 31 \tag{1}$$

Figure 3 depicts the functional relationship between the number of clients that make requests to the instrumentation server, and the necessary communication bandwidth. In order to validate the solution proposed in expression (1), we also show the experimental data obtained from measurements. By comparing the two, we can conclude that our methodology provides a good estimation of the actual resource necessities.

4. Conclusions

Monitoring and control systems based on distributed virtual instrumentation are increasingly popular in various industrial fields. Their emergence causes two stringent necessities. First, we need high level tools that demystify the design process and allow quick development, such as graphical languages. Second, we need specifications and development methodologies that establish reusable patterns and lay common ground across various systems. In this paper, we made use of LabView, a popular graphical language, in order to develop an experimental platform and design a solution to our problem: how to choose and evaluate the necessary communication bandwidth in the context of distributed virtual instrumentation. Future developers can build upon our solution for resource allocation management and network configuration.

The main conclusion drawn from our experiments is that the design of multi-client distributed applications must take into account two factors: the existing communication bandwidth and the amount of data sent across the network. For instance, we ran a couple of experiments on an Ethernet network with ten clients. Each of these clients run on an Intel I3 processor with 4GB of RAM computing system configuration. For two real acquired signals monitored on independent measurements instruments, we concluded that the bandwidth must be at least 500 Kbps, whereas for thirty acquired signals the value must be increased to at least 2 Mbs.

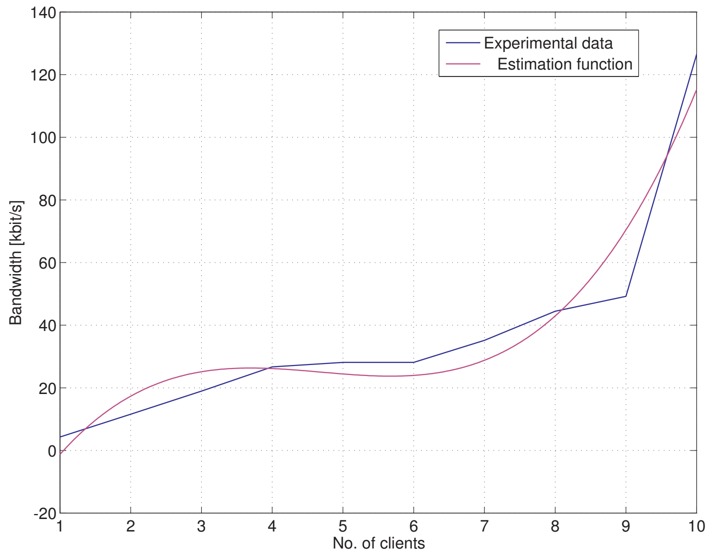

Fig. 3. Traffic load and bandwidth estimation fit function.

Both the solution provided in the experimental platform, as well as the methodology to determine the necessary communication bandwidth, provide reusable patterns in the development of supervision, monitoring and control technologies through graphical programming and virtual instrumentation.

References

[1] Wang JF, Peter WT, He LS, Yeung, RW. Remote sensing, diagnosis and collaborative maintenance with Web-enabled virtual instruments and mini-servers. The International Journal of Advanced Manufacturing Technology, 2004, 24.9-10: 764-772.
[2] Cecchi V, Yang X, Miu K, Nwankpa CO. Instrumentation and measurement of a power distribution system laboratory for meter placement and network reconfiguration studies. Instrumentation and Measurement, IEEE Transactions on, 2007, 56.4: 1224-1230.
[3] Guo Q. A virtual instrumentation-based embedded system integrated with power quality and synchrophasor measurements. In: Electricity Distribution (CICED), 2012 China International Conference on. IEEE, 2012. p. 1-5.
[4] Ma YL, Tian LJ, Qin YL, Jiang T. Grid-Connected Photovoltaic Monitoring System Based on Virtual Instrument. In: Applied Mechanics and Materials. 2014. p. 233-240.
[5] Cheptsov A, Koller B, Adami D, Davoli F, Mueller S, Meyer N, Kranzlmueller D. e-Infrastructure for remote instrumentation. Computer Standards & Interfaces, 2012, 34(6): 476-484.
[6] Ionel R, Pitulice L, Vasiu G, Mischie S, Spiridon OB. Implementation of a GPRS based remote water quality analysis instrumentation. Measurement, 2015, 65: 81-93.
[7] Koniar D, Hargas L, Simonova A, Hrianka M, Loncova Z. Virtual Instrumentation for Visual Inspection in Mechatronic Applications. Procedia Engineering, 2014, 96: 227-234.
[8] Grimaldi D, Rapuano S. Hardware and software to design virtual laboratory for education in instrumentation and measurement. Measurement, 2009, 42(4): 485-493.
[9] Jamont JP, Occello M, Lagreze A. A multiagent approach to manage communication in wireless instrumentation systems. Measurement, 2010, 43(4): 489-503.
[10] Corrado, M., De Vito, L., Ramos, H., & Saliga, J. Hardware and software platform for ADCWAN remote laboratory. Measurement, 2012, 45(4): 795-807.
[11] Naddami A, Fahli A, Gourmaj M, German-Sallo Z, Grif HS, Gligor A. Remote Laboratories in Engineering Education. Scientific Bulletin of the Petru Maior University of Targu Mures, 2015, 12(1):18-23.
[12] Berruti L, Davoli F, Zappatore S. Performance evaluation of measurement data acquisition mechanisms in a distributed computing environment integrating remote laboratory instrumentation. Future Generation Computer Systems, 2013, 29.2: 460-471.