AUTOMATED DCC GENERATION USING LABVIEW AND BLOCKCHAIN TECHNOLOGY

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Abstract − Digital technologies are used in instrumentation and measurements since many years. The use of microprocessors in measuring instruments became a common practice, bringing the advantage of extended information processing at the instrument level, digital interface and remote control. The instrument can be calibrated and verified within an automated system which can carry all the process without the operator interference and to generate in the end the calibration certificate. The paper presents the possibility of joining the calibration of an instrument with a reference source using an automated test system with the Blockchain technology for creating a Digital Calibration Certificate (DCC). As benefits there are the traceability of the DCC, impossibility of being altered and the full history can be maintained in its digital wallet.

Keywords: Blockchain technology, Digital Calibration Certificate (DCC), Virtual instrument, automated test system, data acquisition, reference voltage source

1. INTRODUCTION

Calibration is a process that is usually accomplished after the instrument gets out from the production line. Calibration means measuring the offset and the gain errors [1], [3] and trim the analog circuitry in order to correct this errors. During the factory calibration, the correction values are stored in the nonvolatile memory of the instrument. The errors changes with time and with temperature, making the calibration constants invalid and requiring a new calibration. Depending on the needs, the calibration must performed at least once per year, but it can be earlier (6 or 3 month) if necessary. Automated calibration is usually much faster than the manual calibration.

Modern instruments are programmable [2] via the built-in interfaces, like USB or GPIB. The user can send commands to the instruments for operating them remotely. Including them in a software control loop and sending sequentially commands to the instrument, an automated test loop can be achieved. The simplest case is when both, the calibrated instrument and the reference instrument, are programmable. Thus, the entire calibration process can be fully automated. When one of the instruments has no interface, the process can be partially automated using video processing [4], on single range or function, while switching ranges/functions must be performed manually.

The commercially available software is not suitable in most cases for metrological purposes [1], a custom software must be developed for each instrument.

In [2] an automated calibration system for calibration of electrical sources and measuring instruments like Digital Multimeters (DMMs) has been developed. It is intended for several well known instruments like calibrators (Fluke 5720A and Wavetek 9100) or DMMs (Fluke 8506, Fluke 8846 and HP 3458). The software is built in LabView and allows to control the calibration system, eliminating the human errors and performing statistical processing of the results. Instruments are connected to the host computer via GPIB interface.

In [3] it is presented an automated measuring station for the determination of calibration intervals for DMMs. They are using a Fluke 5500 Calibrator as a standard device and a Fluke 45 a checked instrument. The test is performed every 2 month interval up to 1 year.

In [5] authors present an automated calibration system for DMMs not equipped with Communication Interface. They are using video processing to "read" the numbers provided on 7 segment displays. The process is partially automated, the operator's task being to change the ranges and functions.

In [6] it is described a travelling standard for calibration of data acquisition boards. It is developed around a microcontroller based system which includes 2 digital to analog converters and one DMM. It allows both AC and DC calibration and the system is remotely controlled.

There are several approaches described above, but for all the software is custom design. The system can be fully automated or partially automated, depending on the instruments. But an automated system can be endowed with the feature to automatically create the DCC. As long as the data is recorded in the system in the digital format, the software can automatically create the calibration certificate, based on the recorded data. In most cases the data is saved in files with various formats, so the file can be created with a desired format for the DCC. There are several approaches in the literature for creating a DCC. In [7] the authors describe how to generate the DCC using Excel. They are using the programming environment in Excel for the visual generation of the DCC. In [8] the authors presents several variants of saving the DCC in pdf format for various fields like VNA, electrical energy, or acoustics. The pdf file can have attached the digital calibration certificate.

Since modern instruments have most of them built-in interfaces, they can be used in automated measuring loops [2,

3, 5] or they can perform time consuming operations. Unfortunately, even the interfaces are the same (GPIB, USB), the commercially available software is not capable to perform the calibration. For this kind of applications, it must be particularly developed in these laboratories.

Calibration is one of the activities requesting traceability, allowing the connection with the primary standards. In [10] it is shown the calibrations can be performed on site based on travelling standards, without requiring the presence of any specialized personnel from the metrology lab. Such situation needs an Internet connection and to automatically and securely send the calibration data on a server. The present paper brings as novelty the automatically generating of the DCC during an automated calibration together with saving it as a Blockchain transaction. The DCC is thus validated by the network and cannot be erased afterwards.

2. BLOCKCHAIN...

As per IBM's definition, Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network.

All these transactions are stored in blocks of data, using complex cryptography functions. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree) as in Fig. 1. Once a transaction is executed, all the data remains in the Blockchain permanently. You cannot alter, modify, copy or delete it, you can only distribute it.
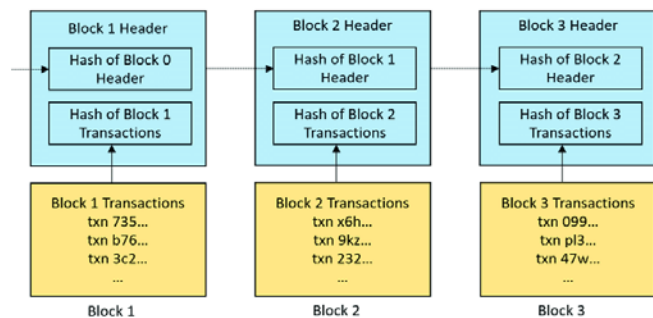

Fig. 1. Blockchain block simplified

In order to migrate the Digital Calibration Certificate on Blockchain, we built a private permissioned Blockchain infrastructure with 3 private nodes, an API and a web platform acting as smart asset management tool (Fig. 2).

Our Blockchain itself is based on X15 algorithm [11] and thanks to its energy efficiency it can even run on a Raspberry pi2. It uses 15 hashing algorithms that are consecutively carried out one after another. We also built it's associated Windows and Linux wallets from which we can natively monitor all the transactions. The infrastructure has been build to run on port P2P Port:10218 and accept commands only on RPC Port:20208. This specific Blockchain feature also adds an extra layer of security.

The API has been build using the opensource jsonRPCClient.php - a simple php class that implements Json RPC client over raw tcp.

The asset management tool works in parallel with the LabView Dashboard allows the user to create a Blockchain identity for the measurement instrument. Basically it uses a specific function, "getnewaddress" from

jsonRPCClient.php in order to remotely connect to the main wallet and store the instrument's details(name and serial) as metadata in a single transaction. The Blockchain address attached to the instrument is converted to a QR code for a better portability and this process is basically the creation of the smart asset on our infrastructure.
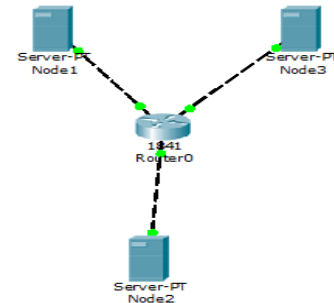

Fig. 2. Local Blockchain node simplified

Then, we use the newly created Blockchain identity to initiate transactions. Each transaction generates an unique transaction id.

The traceability aspect of the whole system is given by the fact that we can trace back in time every transaction and identify each measurement. This can be done directly from the wallet (as a native feature) or by accessing our smart asset management tool.
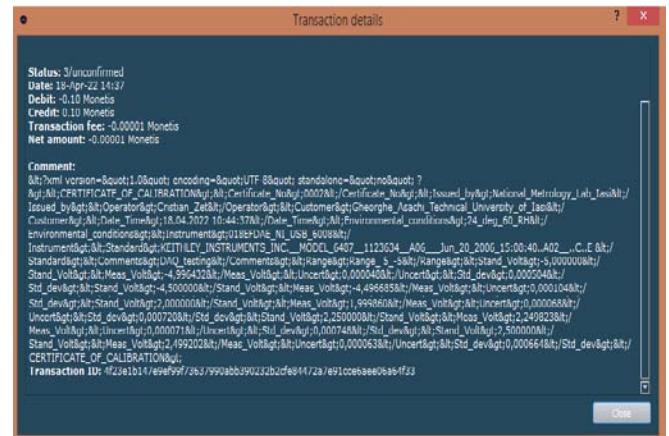

Fig. 3. Blockchain transaction details

The LabView side of the project uses HTTPClient.lvlib to connect to the Blockchain API. It also collects measured values and send them to a specific address as metadata. The data is formatted as .XML, before embedding it to Blockchain which offers an alternative in future verification.

This particular approach offers an extra degree of anonymity and low-cost of transactions in the peer-to-peer (P2P) Blockchain network compared to those in the real world.

3. AUTOMATED TEST SYSTEM FOR A DAQ CARD

In order to exemplify the possibility of embedding a DCC as a transaction using blockhain technology, a data acquisition board (DUT) calibration using a standard programmable source (Fig. 4) has been considered.
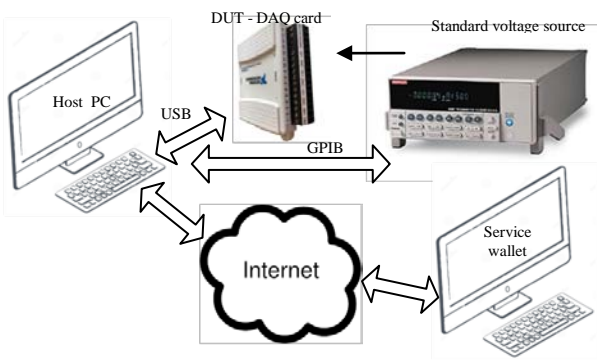
Fig. 4. The schematic of the calibration arrangement

The DUT is a multifunction NI USB 6008 data acquisition card. It has 8 analog inputs with 2 types of connections: differential and single ended. As long as the first one allows several measuring scales, the calibration was performed for channel 0 using this connection: AI0+ and AI0- being connected to the standard generator. The DAQ is connected at the host PC using the USB interface. The programmable voltage source is connected to the PC through the GPIB interface. In order to perform an automated calibration, a virtual instrument has been realized in LabView. The front panel of the VI is presented in Fig. 2.
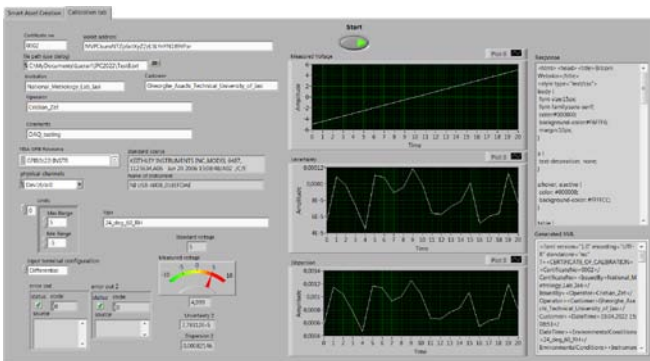

Fig. 5. The automated calibration VI front panel

If the instrument to be calibrated is not registered as a smart asset, the operator can choose the tab "Smart asset

creation". After inserting the "Device no" the program will query the device and will get the serial number and board type. By concatenating the two strings, it will ask the Blockchain platform to create a wallet for the device and will return the wallet address (like MMZo6BKSvw JhMJZ2vvGMGyaA8fexGwmE4C). The new address will appear also in the wallet application. This address must be copied and pasted in the corresponding field in the Calibration tab.

Moving to the "Calibration tab", the operator must fill in the fields for the certificate information, like the certificate number (Certificate no), the certificate issuer name (Institution), the operator name (Operator), the customer name (Customer) and the comments field (Comments). Next, he has to set the connection type (input terminal configuration), the scale limits (Limits) and the source GPIB address. The environmental conditions can be specified as an input field (T&H), in case the room is environmental controlled, or they can be measured using a remote environment monitor station. Before starting the instrument, the operator has to fill in the wallet address (Wallet address). If the calibrated instrument has already one he will fill it in. If it is calibrated for the first time, he has to create the instrument Blockchain identity. Once the DUT and the standard source are connected, the operator can start the program.

The first task is to read the instruments IDs and serial numbers directly from their firmware, which will be added to the certificate. Next, the instruments will be initialized with the working parameters. In our case, the standard voltage source will be configured with the output range, the output current limit, the output is set to 0V and the output is set to ON. Following, the header of the Calibration certificate is build with the subVI XML_DCC_Head. The information introduced by the operator in the corresponding fields is flattened into XML string. Because that some special characters are not allowed in this format, they have to be removed from the instrument identification string and replaced with underscores or dots.

The block diagram of the VI is presented in the Fig. 3. The main program consists of two for loops. The outer one corresponds to the number of scales the instrument has, while the inner one correspond to the number of calibration points.
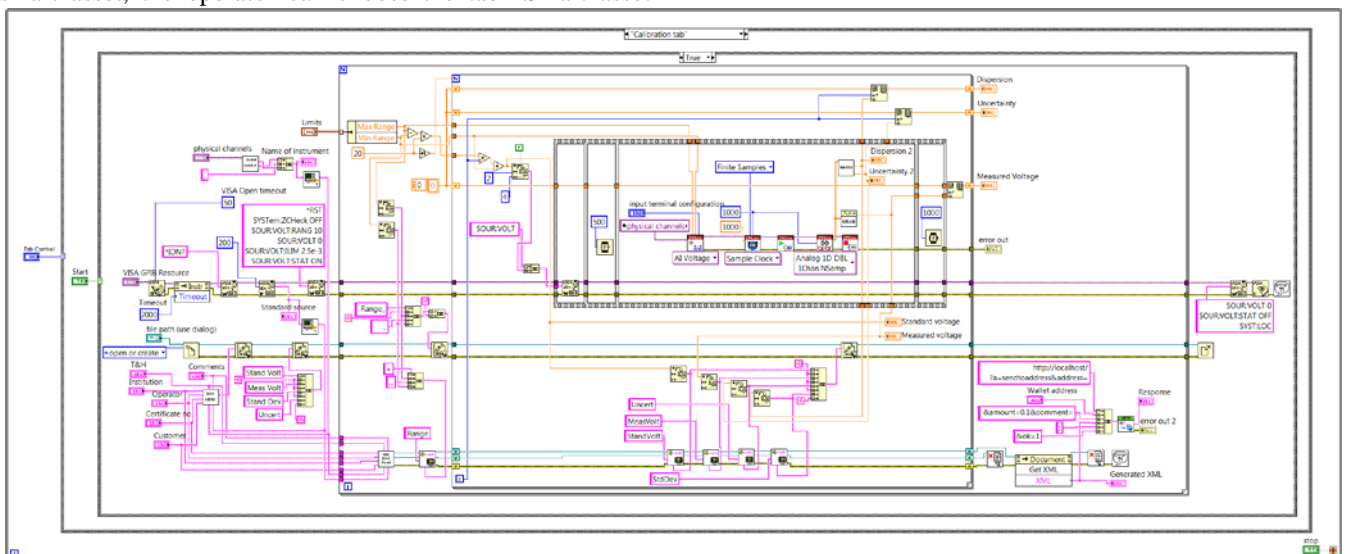

Fig. 6. The schematic diagram of the automated calibration VI

Each range to be tested, means a Blockchain transaction with its own DCC. According to the scale limits, the program calculates the test values to be applied, by dividing the scale width to the number of desired test points. In our example a number of 20 points was chosen, equally distributed from the lower scale limit to the higher scale limit. The scale limits are added into the certificate. The inner loop runs for 20 times, checking one test value for each run. The DAQ card is set to take 1000 measurements with the sampling frequency of 1kHz. This means about 1 second for each point. The standard value is applied at the board input, the measurements are performed and the program calculates the mean, the standard deviation and the uncertainty using the Gauss distribution. These values are added to the XML string for each tested point. The standard voltage in our case is increased in steps from the lowest limit to the highest limit of the scale, and the resulting data are appended to the XML file. After a range is tested, the XML data is recorded into Blockchain as a transaction. The transaction has an amount of tokens to be "spent" and the calibration information attached as metadata. The process continues with the next measuring range, whose resulting data will represent another transaction in the instrument wallet. During the measurement process the operator can follow the instantaneous results on the display and as graphs at the end of a range test. The calibration data is saved also in a .txt file on the host computer for further visualization and processing. The whole process runs automatically, without the operator interference and the data is sent directly to the Blockchain.

4. RESULTS AND CONCLUSIONS

Assuming that the structure of national metrology institutes involves a central entity and territorial entities, each one must have an own wallet (Fig. 7). Each wallet is associated to a node and each node will validate each transaction. When an instrument is calibrated by an institute in territory, it will have its own identity in the wallet and it will send several transactions to the Central wallet;. Even if the Internet connection is absent, the transaction will be recorded in the local wallet and synchronized with the Blockchain network after the internet connection is restored.

In our experiment we created two identities for 2 DAQ boards and performed the calibration for 3 of their measuring ranges. For each card 3 transactions were recorded in the wallet. The results are presented in Table 1

Table 1. Calibration results.

Parameter	DAQ card 00E1AE03	DAQ card 1018EFDAE
Uncertainty ±5V	3.464mV	2.417mV
Uncertainty ±2.5V	2.48mV	1.33mV
Uncertainty ±1.25V	1.949mV	0.78mV
Linearity ±5V	0.28LSB	0.32LSB
Linearity ±2.5V	0.24LSB	0.2LSB
Linearity ±1.25V	0.27LSB	0.26LSB

In conclusion we can obviously see the use case where a group of metrology centers become Blockchain nodes and they can reach the ability to create DCCs and the public result can be seen in a secure, decentralized and easy way. This translates into an enhanced portability of data at a fraction of the cost of the current solutions.
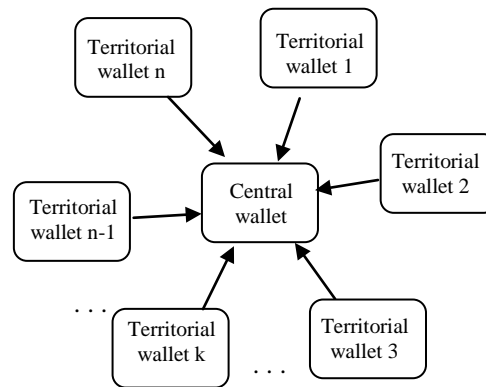

Fig. 7. A possible metrology Blockchain structure

REFERENCES

[1] ***, *Calibration Procedure*, National Instruments Corp, 322314B-01, February 2000.

[2] H. M. Abdel Mageed, A. M. El-Rifaie, "Automatic Calibration System for Electrical Sourcing and Measuring Instruments", *12th International Conference on Environment and Electrical Engineering*, pp. 1-5, Wroclaw, Poland, 5-8 May 2013, https://doi.org/10.1109/EEEIC. 2013.6549578

[3] C. De Capua, D. Grillo, E. Romeo, "The Implementation of an Automatic Measurement Station for the Determination of the Calibration Intervals for a DMM", IEEE Symposium on Virtual Environments, Human-Computer Interfaces and Measurement Systems, pp. 58-62, La Coruna, Spain, 10-12 July 2006

[4] F. Martín-Rodríguez, E. Vázquez-Fernández, Á. Dacal-Nieto, A. Formella, V. Álvarez-Valado, H. González-Jorge, "Digital Instrumentation Calibration Using Computer Vision", ICIAR 2010, Part II, LNCS 6112, pp. 335–344, Springer-Verlag Berlin Heidelberg 2010.

[5] G. Grzeczka, M. Klebba, "Automated Calibration System for Digital Multimeters Not Equipped with a Communication Interface", MDPI Sensors 2020, 20, 3650

[6] A. Carullo, M. Parvis, A. Vallan, " A Traveling Standard for the Calibration of Data Acquisition Boards ", IEEE Transactions on Instrumentation and Measurement, Vol. 53, No. 2, April 2004

[7] D. Röske, "A visual tool for generating digital calibration certificates (DCCs) in Excel ", Measurement: Sensors, Volume 18, December 2021, 100175, https://doi.org/10.1016/j.measen.2021.100175

[8] G. Boschung, M. Wollensack, et all, " PDF/A-3 solution for digital calibration certificates ", Measurement: Sensors, Vol. 18, December 2021, 100282, https://doi.org/10.1016/j.measen.2021.100282

[9] T. Mustapää, P. Nikander, D. Hutzschenreuter and R. Viitala, "Metrological Challenges in Collaborative Sensing: Applicability of Digital Calibration Certificates", Sensors 2020, 20, 4730; doi:10.3390/s20174730

[10] A. Carullo, M. Parvis and A. Vallan, "Security Issues for Internet-Based Calibration Activities", IEEE Instrumentation and Measurement Technology Conference Anchorage, vol. 2, Alaska, USA, May 21-23, 2002, https://doi.org/10.1109/IMTC.2002

[11] Md Sadek Ferdous, M. Jabed Morshed Chowdhury, M. A. Hoque and A. Colman, "Blockchain Consensus Algorithms: A Survey", shortcomarXiv: 2001.07091v2 [cs.DC] 7 Feb 2020, https://arxiv.org/pdf/2001.07091.pdf