Challenge and future trends of distributed measurement systems based on Blockchain technology in the European context

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***Abstract*— In these years, Blockchain technology is growing in importance thanks to cryptocurrencies. This technology offers many features such as the immutability of data stored in the data chain, the replicability of data in nodes, the management without a central repository, etc. These features are widely adopted also in other fields such as in distributed measurement systems. Although the Blockchain technology is widespread worldwide, there is still a legislative gap in the adoption of this technology in various states. This paper will examine the challenge and future trends on distributed measurement systems based on Blockchain technology in the European context. In particular, critical aspects of Blockchain technology will be examined under GDPR point of view and in particular in the management of data and privacy. The advantages and disadvantages of using Blockchain technology in applications such as the Internet of Things and smart contracts will be discussed and some aspects of legal metrology in Blockchain networks will be analyzed. At the end, future trends in Blockchain technology applied to distributed measurement systems will be shown.**

Keywords — Blockchain, GDPR, IoT, Smart Contract, Distributed Measurement Systems

I. Introduction

Nowadays, in every industrial, commercial and domestic sector, modern measurement devices are integrated into data communication systems and frequently operate on large areas. Examples of applications are smart grids, but also networks for monitoring and controlling complex industrial systems. The current trend is that of internet-connected systems that can be accessed remotely. The main problem for these devices is data security. This problem is addressed with different approaches, in the various sectors. A conclusive solution in the field of measuring instruments has not yet been defined.

The main solutions do not innately support trust management and privacy protection. Consequently, a technology that guarantees data protection, encourages the exchange of information and reduces costs is highly desired. A possible solution is based on the adoption of reliable methods and techniques, already in use in other sectors.

The blockchain technology is implemented in a distributed fashion, without a central repository and usually without a central authority. It applies to electronic currency, with the main advantage of allowing direct electronic financial transactions between users without the need for a third party. Measurement instrumentation can benefit considerably from the application of this technology, as it is undoubtedly the characteristics it can offer in terms of security and data protection

According to the globally accepted traditional definition, the term "Blockchain " identifies, "an open and distributed database capable of recording transactions in an efficient, verifiable and permanent way" [1-2], and formalizes the conceptual idea theorized by Satoshi Nakamoto [3].

In October 2017, the United Arab Emirates defined a new "Smart Government" model based on Blockchain technology, used to implement efficiency and quality of public service, with the document "UAE Strategy for Artificial Intelligence (AI) 2031". This model envisages a significant reduction in transaction costs in all sectors and government levels. Furthermore, the "Dubai Blockchain Strategy" was adopted, with the aim of making Dubai "the happiest city on Earth", thanks to the widespread use of Artificial Intelligence and Blockchain technology, able to guarantee greater economic opportunities, as well the creation of new innovative industries and greater government efficiency [4].

In China there is an interesting pronunciation of the governate that recognizes the relevance of the Blockchain. In September 2018 the Supreme Court established the binding legal value in disputes, of authenticated tests carried out with Blockchain technology. In particular, "the courts will recognize the digital data presented as evidence, if the interested parties have collected and archived this data via Blockchain with reliable digital signatures or through digital platforms capable of demonstrating the authenticity of that technology used" [5].

In the US regulatory landscape, it is possible to focus an increasing number of legislative interventions dedicated to the regulation of Blockchain technology. By way of example, the

House Bill 2602, adopted on 12 April 2018, modifies the status of the State of Arizona, with respect to the prohibition of introducing local regulations regarding Blockchain. In particular, it is no longer possible to prevent and / or limit the management of transactions using Blockchain technology [6]. The state of California with the Bill n. 838 approved on 28 September 2018, defines the essential characteristics of the Blockchain technology and authorizes joint stock companies that do not issue listed securities to include specific provisions in their statute for the registration of emissions, transfers and storage made using Blockchain technology [7]. This also applies to the states of Connecticut [8], New Jersey [9] and New York [10].

The European Parliament, following a series of initiatives promoted by the European Commission [11], acknowledged the importance of Blockchain technology with the Resolution of 3 October "on distributed register and Blockchain technologies: creating trust through disintermediation". In particular, Blockchain is defined as a tool "that can democratize data and strengthen trust and transparency", as it "strengthens the autonomy of citizens" and improves "efficiency of transaction costs by eliminating intermediaries and intermediation costs, in addition to increasing the transparency of transactions " [12].

In Italy, the Ministry of Economic Development, following a public call, in December 2018 selected thirty members of the "High-level expert group for the preparation of the national strategy on technologies based on distributed and Blockchain registers" [13]. In 2019, with the "Simplification Decree", the Blockchain and the smart contract were adopted by Italian law. The identification of precise legal frameworks, together with the European anti-money laundering provisions and the reports published by the Bank of Italy, favours the general acceptance of cryptoactivity and the development of new economic activities [14].

This paper will examine the problems and advantages of using Blockchain technology in distributed measurement systems. The European background and the GDPR will be shown. The use of this technology will be taken as examples to the Internet of Things and Smart Contracts to conclude with future trends applied in distributed measurement systems.

II. THE BLOCKCHAIN TECHNOLOGY IN THE EUROPEAN CONTEXT: GDPR

In the last two years in the European community there has been a lively debate on the relationship between the application of Blockchain technology and the reference regulatory context. The interest lies both in some of its revolutionary applicative effects, and in its potentially conflicting relationship with Regulation (EU) n. 2016/679 on General Data Protection Regulation (GDPR), which came into force already in the spring of 2016, but effective from 25 May 2018 [15].

The Blockchain is a distributed technology because it uses different "nodes", individuals or organizations, that maintain a copy of the distributed register. Since, in principle, a Blockchain network consists of a large number of server nodes that simultaneously hold copies of the same data, there can be two types of nodes: 1) validating nodes, i.e. nodes enabled to add data to the register, based on the chosen consent algorithm; 2) participating nodes, which synchronize copies of data (not necessarily all nodes retain all data).

The difficulty in the compatibility between Blockchain and GDPR derives from both the type of nodes and the type of chain. In fact, there are three types of chains: 1) public and permissionless; 2) public and permissioned; 3) private and permissioned.

In the first case, each node can participate in the Blockchain and become a node validating the transactions. In a public and permissioned chain, everyone can participate as a node and view the data, but only some pre-authorized actors can become validating nodes and add data to the registry. Finally, choosing a private permissioned Blockchain means opting for a structure in which the validating nodes and the participating nodes must both be approved by a governance of actors, even grouped in a consortium of companies or government agencies.

In the light of this complex architecture, compliance privacy does not depend on technology, but on how it is used and implemented. In view of this and the fact that there are different types of Blockchain, the thesis, that the Blockchain technology is incompatible with the architecture of the roles and responsibilities of the GDPR is not necessarily true.

The technologies of a distributed register appear, by their nature, to be scarcely related to a centralized model, such as the one underlying the legislation on the protection of personal data, which converges the responsibilities to the data processing manager. By choosing the most suitable type of Blockchain and carrying out the necessary legal assessments, it could coexist with the regulatory framework currently in force.

Furthermore, advanced cryptographic solutions for the data distributed on the Blockchain and measures that guarantee an efficient exercise of the rights pursuant to arts. from 15 to 22 of the GDPR, are some of the precautions that must be kept in mind with a view to privacy-by-design and by-default.

III. THE BLOCKCHAIN TECHNOLOGY AND THE INTERNET OF THINGS

Internet of Thing (IoT) and Blockchain seem to have formed the perfect combination in both industrial and consumer environments [16]. The ability to access an ever-increasing number of distributed systems, which provide information that is chained together, has created a new concept of distributed system and conceptualized the idea of merging the IoT with the Blockchain technology [17-20].

The Blockchain technology can provide billions of connected IoT devices to communicate in a safe but at the same time decentralized ecosystem, which allows user data to remain private and thus remove the main weakness of centralized systems [21].

The research and intelligence company IoT Analytics, focused on the Internet of Things, M2M and Industry 4.0, has published a research expressly dedicated to the relationship between Internet of things and Blockchain: "Industrial & IoT Blockchain Market 2019-2023". The study highlights the existence of a substantial value in the Blockchain technology (see Fig.1). To date, 174 million dollars have been spent on the investment market of Industrial & IoT Blockchain and many have been dedicated to pilot projects in the initial phase. It is expected that 573 million dollars will be developed in this market by 2023, thanks to the encouragement of pilot project results and ongoing investments [22].

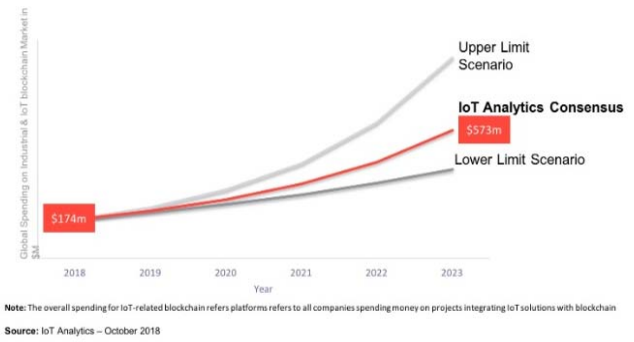

Fig. 1. Industrial & IoT Blockchain Market 2019-2023

Fig. 2. Development of the Blockchain initiatives in power sector

A Deloitte report [23] highlights that Blockchain and IoT technologies are in constant evolution and need to mature in order to support the new applications. The Blockchain still suffers from some limitations when certain performance and scalability must be guaranteed, especially for information sharing and trust. The IoT infrastructure should be highly resilient and completely secure but, as is known, there are difficulties in this regard. Basically, the combination of the two technologies is promising, but it still needs time to mature and be applied on a large scale.

In March 2019, the European Union Blockchain Observatory & Forum held a workshop on Bockchain, AI and IoT. The workshop showed that the data has been stored in a way that they cannot be modified. In addition, a look at Ledger's live or near-live projects for intelligent hardware or green energy, confidence in fuel consumption, production of luxury goods and water conservation was also provided [24].

IV. THE BLOCKCHAIN TECHNOLOGY APPLIED TO SMART CONTRACTS

The Distributed Ledger Technology (DLT) is a relatively recent technological innovation that has wide-ranging implications for many sectors. While the cryptographic technologies behind Blockchain have been around for some time, their combination in a useful package has been truly innovative [25]. In the energy sector, this combination is connected to the proliferation of distributed energy resources and grid-interactive devices, as shown in Fig. 2 [26].

This decentralized includes the management of power generation and distribution, sales, billing, payments, innovative financing mechanisms, contract management, and trading and incentives: in a single word “smart contract” [27].

As defined by Nick Szabo in 1993, the intelligent contract is "a computerized transaction protocol that executes the terms of a contract" [28]. The terms of an agreement between two or more parties are programmed in code form (set of instructions) and stored in a Blockchain. When the specific conditions described in the code are met, the specific actions defined in the code are automatically started. So, for example, the delivery of the products could activate an instruction to make a payment. This instruction could, in turn, activate other instructions in other smart contracts, for example to change currency or place orders.

Smart contracts find a natural application in the sale of electricity in smart grids. The most prominent smart contract Blockchain platform is Ethereum [29], that has a built-in Turing-complete programming language, which allows the definition of smart contracts and decentralized applications.

The European Parliament, in the "European Parliament resolution on distributed ledger technologies and Blockchains: building trust with disintermediation (2017/2772 (RSP))" [30] stressed with regard to smart contracts: 1) the need for the Commission to carry out an in-depth assessment of the potential and legal implications, such as risks related to jurisdiction; 2) the need to give certainty to the validity of an encrypted digital signature as a fundamental step to favor smart contracts.

At the same time, it invited the Commission to promote the development of technical standards at the level of the competent international organizations, such as ISO, ITU and CEN-CELENEC and to conduct an analysis of the existing legal framework in the various States, in relation to the applicability of the smart contracts also trying to strengthen their legal validity.

In this context, in 2018 the European Law Institute began to design the legal infrastructure to maintain existing EU instruments in the areas of cross-border execution of requests, procedural law and the application of foreign law, to facilitate the use of new technologies [31] as a call to examine the legal and regulatory aspects of the Blockchain technology [32].

V. ASPECTS OF LEGAL METROLOGY IN BLOCKCHAIN NETWORKS

The main purpose of legal metrology is to protect and guarantee confidence in measurements. Legal metrology makes a contribution to the simultaneous protection of consumers. The International Organization of Legal Metrology (OIML) has established to contribute to the harmonization of these regulations across national borders, to ensure that legal requirements do not hinder trade. The software requirements for this purpose are formulated in the OIML D 31 document [33].

WELMEC [34] is the European Commission to promote cooperation in the field of metrology and to establish a directive on measuring instruments [35]. With Directive 2014/32 / EU of the European Parliament and of the Council [36], which is based on Directive 2004/22 / EC [37], known as the Measuring Instruments Directive (MID), it is the European Union that establishes a European market for measuring instruments used in different Member States.

The purpose of the MID is to protect the consumer and create a basis for fair trade and trust in the public interest. The OIML D31document and WELMEC Software Guide 7.2 are probably the most widespread standards for software-controlled Measurement Instrument (MI) design, deployment and inspection [38]. Both documents are taken as reference by metrological agencies, notified bodies and manufacturers in different countries [39]. Although the use of Blockchain is important, the application of Blockchain technology in legal metrology is still an open activity [40].

VI. NEXT TREND FOR BLOCKCHAIN TECHNOLOGY

The development of distributed measurement systems based on Blockchain technology is the trend of the future [41]. The possibility of integrating measurement objects into Blockchain networks provides a way to guarantee the authenticity and immutability of the measurement result.

In recent years, new projects are being developed aimed at merging Blockchain with distributed database technology. For example, the project Catena is a distributed database based on a Blockchain, accessible via SQL. A Catena blockchain contains SQL transactions that, when executed in order, lead to the agreed-upon state of the database. The transactions are automatically replicated to, validated by, and replayed on participating clients.

Another example is the BigchainDB project [42], based on Tendermint [43] and MongoDB [44]. The data is structured in resources that uses data from the traditional SQL database structure in the tables. The idea of BigchianDB is that everything can be represented as a resource. A resource can model any physical or digital object from whose transition represents a data transfer. BigchainDB has created a distributed database, IPDB, which uses Blockchain technology whose governance is entrusted to a non-profit foundation [42].

An important open point is the software interface to use the distributed system. If at the network infrastructure level, Blockchain technology provides decentralization, data protection and redundancy, it becomes indispensable to define a way in which users can use this technology both to memorize measurement data and to find such information. A solution is to use a web interface built with a standardized, open source and multiplatform technology. Among the existing technologies (API-REST-JSON-etc.) Web services still offer the best compromise between flexibility and usability of a service accessible on the Internet [45-50].

Another open task is the use of measurement data for cooperation and data fusion between different distributed smart measurement systems. In this regard, multi-agents provide an important key in the use of the network infrastructure based on Blockchain technology as they offer scalability, modularity and integrability [51-52].

VII. CHALLENGES FOR BLOCKCHAIN TECHNOLOGY IN DISTRIBUTED MEASUREMENT SYSTEM

When turning from a central IT to more decentralized systems in the energy sector, more efforts on system integration have to be spent. The integration paradigms of EAI and SOA may be used for communication, automation as well as for secondary and primary IT. Internationally standardized solutions already exist to simplify this, like for instance the IEC 62357 SIA, which can be realized using a SOA, or the IEC 62541 OPC UA as a SOA-based approach for data exchange. Nevertheless, there are still gaps that require harmonization between semantic and syntactic interfaces. In these years there have been attempts to create a general approach to distribute measurement systems, and in particular to Smart Grid development with the focus on its architecture[53]. The most widely known representative of these attempts is the Smart Grid Architecture (SGAM) [54], a framework representing a layered outlook on smart grid infrastructure, consisting of five layers (bottom-up): component layer, communication layer, information layer, function layer, and business layer. This model became well known mainly in Europe, where many power suppliers use it as the reference architecture for their Smart Grid design [55]. The SGAM communication layer is based on IEC 61850. These protocols can run over TCP/IP networks or substations, using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying. Blockchain technology is based on TCP/IP protocol on which different blockchain protocols are developed (Ethereum, etc..). For these reasons, the blockchain network can share the communication level of Smart Grid networks, because they use the same protocol for levels 2 and 3 of the ISO / OSI stack.

The real limitation in using Blockchain technology is the bandwidth that plays an important role on the overall performance of the system, because most remote systems do not have sufficient resources to handle large amounts of data. Furthermore, if the nodes take too long to communicate data between them, the risk is making the network asynchronous destroying the value of timestamp transactions. For this reason, many developers are working to implement new technologies in and around blockchains, which help reduce bottlenecks with latency and network bandwidth [56].

Although there are potential advantages in applying Blockchain technology to distributed systems, however, that technology is still young. The energy consumed by transition is one of the major challenges to overcome as it is the basis of the Blockchain consensus mechanism. The efficiency of the work test protocol is rather poor. In fact, the annual energy consumption of Bitcoin and Ethereum Blockchain is equal to 52.5 TWh and 15 TWh, respectively. The sum of these consumptions is greater than the total annual energy consumption of a country like the Czech Republic. This result shows the relationship between the energy consumption of the Blockchain technology in relation to the application in the electricity system.

Another challenge to overcome concerns the relationship between computing power and increased safety in Blockchain systems. Mining nodes use computational power to provide network security. When the computing power of the network has reached a limit level, the performance of the Blockchain network does not increase if the computational power is increased, but rather there will be a waste of energy.

Another very important challenge to be addressed mainly concerns the control of electricity flows which is the focus for the researchers nowadays [57]. The control of power flows within the electrical power system could be achieved by segmenting the electrical grid into multiple cells consisting out of the transmission grid and distribution grid. These cells represent a small segment of the electrical grid where a balance between load and generation of electrical power have to be held.

These cells are smart metering devices which executes control within the specific cell and communicates with the decentralized computing platform based on the Blockchain network. In fact, the transition role of electricity between two elements of the Blockchain network should be determined based on the available distribution and transmission capacity, the transport cost and the cost of the transmission and distribution equipment. In this way the decentralized calculation platform can determine the optimal route and the control could be applied in case of unforeseen events, interruptions or power imbalances [58].

Among the main challenges to be faced for the management of power flows, the balance between the increase in additional complexity of the quantity of cells, compared to the operation of the control of energy flows, is an important task. In fact, if the power system is divided into several cells, their increase also grows the total complexity of the network, with respect to the functioning of the control with an increase in the installation cost and the processing capacity required by the Blockchain [59].

Another important challenge concerns the functioning of the power flow routing devices in the Blockchain network and the communication that these devices have with the decentralized computing platform. The delay in the transmission of messages between the nodes of the network with respect to the functioning of the control mechanism and the actual load of the lines, this might lead to unintentionally overloading lines within the transmission grid or distribution grid [60].

Finally, the challenge on security has been grown in importance in these years. In [61] the scenario has been presented in deep and it can be concluded that cyber and physical attacks are deeply connected and must be addressed to ensure proper management of the whole system. The methods used to attack varying in type, form, and impact, such as 1) time synchronization attacks, 2) GPS spoofing attacks, and 3) Denial-of-Service (DoS) attacks. The FDI attack is the most difficult to prevent because it closely imitates the normal distribution of the measurements of the power grid which is also known as stealthy attack. This kind of attack manipulates or injects false data either in the measurements or the control signals to alter the dynamics the power grid [62]. The methods used in the field of Cyber-Security to defend a system against attacks are divided into: methods based on protection and methods based on detection. Protection-based methods strengthen the network by introducing redundancies in the data. Detection-based methods use Bayesian models to detect anomalies. These methods have strong limitations in the FDI attack. For these reasons, Blockchain technology can provide a solution due to its intrinsic nature of data immutability and consensus management. Measurement systems themselves become the nodes of the distributed network that encapsulates the measurements in the communication node so as to reduce the entire measurement chain. As an example, in [63] a Blockchain application for monitoring application in smart grid has presented where special attention to the security and immutability of data has been analysed.

VIII. CONCLUSIONS

In this paper the trends and the challenges of Blockchain technology has been presented for the developing of distributed measurement system in European context. Starting from an overview of the adoption of Blockchain technology in different states, the European context has been presented in depth and the integration of GDPR with Blockchain technology has been shown. The Internet of Things and smart contracts are some of the technologies of distributed measurement systems that create a starting point for the integration of Blockchain technology with established technologies in systems management. Another important aspect is how the legal metrology melts with Blockchain technology and how it has been implemented especially in economic aspects. Finally, the challenges that the Blockchain technology has yet to face in order to become so applied in the various contexts of distributed measures have been presented. The European context still has limitations in the use of this technology due to the regulatory gap in data management and privacy. This gap will surely be filled in the coming years as other nations have already done. In conclusion, Blockchain technology can certainly be applied to distributed measurement systems.

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