2018 IEEE 11th International Conference on Service-Oriented Computing and Applications

IoT Blockchain Technologies for Smart Sensors based on Raspberry Pi

Víctor Román
ETSII
Universidad Politécnica de Madrid
28006 Madrid, Spain
v.roman.aragay@hotmail.com

Joaquín Ordieres-Meré
PMQ Research Team, ETSII
Universidad Politécnica de Madrid
28006 Madrid, Spain
j.ordieres@upm.es

Abstract

The aim of this paper is to propose an Internet of Things system that collects, sends, stores, and publishes relevant data using a Raspberry Pi as the smart sensor. Distributed Ledger Technologies (DLT) from BigchainDB and IOTA are used to store data in a blockchain-like database, and to publish a temporal statistic data summary respectively, in addition to store the data streams in a SQL database. The collection, storage, and publication of the data is free and almost instantaneous. This system can become a source of evidences to different types of stakeholders all around specific businesses getting benefits from keeping the level of trust along its value chain.

Keywords— Sensor Data, Blockchain, Internet of Things, BigchainDB, IOTA, Raspberry Pi, Business Application.

I. Introduction

Nowadays goods distribution, and supply chain operations are processes carried out with different lack of transparency among the various actors and entities involved. The lack of data availability from monitoring activities reduces managerial capabilities, which leads to significant costs not only in the interchange of information, across the different interested parts but also in loses due to distribution failures which could be prevented or rapidly solved. As a driven application, the case of distribution of frozen food is paramount of those effects. Specific conditions related to temperature, pressure and humidity must be provided during all the processing and delivering chain. Otherwise, significant losses can happen, either because of direct damage of food or because of biological damage to the consumers.

In the case used as example, the monitoring of the temperature, pressure and humidity status, become a vital part of the process. It is in this context where authenticity and integrity of data that regards to these processes, such as real time geo-position and environmental status, is crucial for the control and the optimization of those distribution operations. Most of the existing solutions for such required control only provide detailed, accurate, and timely information to the operator (control flow applications) but not to all the other stakeholders.

Currently we are embracing the fourth industrial revolution, in which the digitalization and cooperative coordination of the productive units are going to suppose unprecedented development of the industry and creation of value [1].

This intelligent industry will be based on the digitalization of absolutely each one of the parts that integrate and form part of the productive processes and will use technologies such as the Internet of Things (IoT), communications Machine to Machine (M2M), platforms in the cloud and 3d printing, among others.

In this new paradigm, the data will no longer be a consequence of the manufacturing process but will have business value for themselves. As an example of the significance with which this transformation of the industry is taking place, the existence of platforms such as Platform Industrial Data, Digital Manufacturing Commons or SkyWise [1]–[3], whose objective is the exchange of production and manufacturing data and for facilitate predictive maintenance tasks.

The IoT technology is especially interesting in this revolution, to the point that a new specific term was coined to refer to the application of this technology to context 4.0: Industrial Internet of Things or IIoT. The devices that are part of these scalable and integrable ecosystems must be subject to an extremely effective management, since authentication and communications between the different cyber physical systems take on a major importance, failures in the collection, processing or storage of the generated data can have catastrophic consequences throughout the production chain and even impact on human losses.

In this kind of contexts is where the combination of Distributed Ledger Technologies and IoT play a paramount role in enabling the trustworthy sharing of immutable and reliable information, by using the proposed platform, where all the stakeholders can get instant access to relevant data. Therefore, both trustworthiness and management capabilities through all the value chain can increase significantly.

Therefore, the decentralized, immutable, and integrated management of data is of significant importance, and it is in this context that Distributed Ledgers and Blockchain-Like technologies can provide a differential value.

In addition, Blockchain can be integrated through communication protocols between machines, allowing the creation of a new economy between the devices themselves in which they can reach agreements on supplies of raw materials, energy, parts, maintenance and even logistics from Smart contracts or Smart Contracts whose payment will be executed automatically once the previously established conditions are met[4]. There are already examples of micropayments through the Tangle with sensors that sell their data, and electric cars that trade with electric power with recharging points.

It is remarkable the case of the company of international transport of containerized merchandise, Maersk. It is a Danish company with the largest market share in its sector, with a range between 18 and 20% of it. Currently, the cost of transporting a container, due to the permits and procedures to be carried out with the countries involved and the pertinent

978-1-5386-9133-5/18/$31.00 ©2018 IEEE
DOI 10.1109/SOCA.2018.00038

IEEE computer society

authorities, is greater than the cost of the physical transport of the container itself. So, it is a clear case of use in which the integration of Blockchain technologies can automate processes, providing instant access to all the parts involved to the operation's information [5]. Furthermore, the complete trust in the integrity and immutability of the data, may speed up and therefore significantly reduce management costs. In addition, in this context, the integration with IoT technologies would allow the tracking and control of all cargo transported and therefore the appropriate action in case of need.

Major problems happen when the stakeholders include a significant number of people and trust between participants require a proof of work in the classical sense, which is mining the blockchain, as the reward cost can make senseless the data exchange, or to impose unwanted extracosts.

The goal of this paper is to present a system that combines the discussed technologies of Distributed Ledgers and IoT to allow the free, instantaneous interchange of data (environmental data in the particular application), store it both in a local server and in a decentralized one, while publishing periodically a statistic summary in the distributed ledger. Next, the solution obtained will be validated appropriately. Finally the discussion of future lines of research and conclusions will be presented.

II. CONTEXT AND RELATED ASPECTS

In this section, the major intervention areas are depicted in the following points.

A. *Data Collection*

According to the motivation to provide evidences about the proper management of frozen food, a set of sensors will be configured into a single board computer (SBC) such as a Raspberry Pi, mainly because of its versatility and low price. Based on its characteristics, communications but also intelligent data management can be implemented.

B. *Storage of Data in a Remote Server*

Environmental data is transmitted through TCP/IP protocols, including different channels as GPRS, 4G, 5G, etc., to a remote server. A relevant goal is to have the system decentralized and non-dependent of a single entity, which could loss data in case of malfunctioning. A Distributed Ledger based technology to store the collected data will be adopted.

C. *Computation and Publication of Periodal Statistic Summary*

A statistic summary of the collected data will be elaborated, and it will be published periodically to other Distributed Tecnology in which all the interested parts could have instant, direct, and reliable access.

Currently, there are thousands of available sensors in the market specifically designed for IoT and IIoT applications, compatible with SBC. Although the particular adopted sensors are not relevant enough, in order to get detailed perspective of the implementation, details are provided. The SenseHat sensor was selected as it uses to be one of the most complete and reliable sensors available. It enables the collection of several measurements such as: temperature, humidity, pressure, magnetic field, accelerations and orientation. The connection to the Raspberry Pi is made via de GPIO pins and the sensors are connected via l2c bus. The Raspberry Pi runs a Python program to collect, adequate, and send the collected data.

Regarding the communication protocols, between the Raspberry Pi and the internet located servers, there are several alternatives, some of them with capabilities of good performance:

- CoAP (Constrained Application Protocol): A widely used protocol for Machine to Machine communication and Wireless Sensor Networks. It is designed as a simple translation of HTTP and implements Rest model, which improves greatly the easiness of usage, the weight of the shared data and power consumption [3].
- TiniySOA: Is a middleware commonly used in Wireless Sensor Networks, it provides web services which facilitate the interchange of sensor data [4].
- MQTT: It is an open source protocol developed and optimized for M2M communication. It is especially designed for devices with lightweight consumption, low bandwidth high latency and it uses a publication/subscription architecture, with a central node as a server or broker which can have up to 10.000 clients which receive the messages sent by the broker [6].

Considered all these technologies, the MQTT is selected to establish proper communication between The Raspberry Pi, acts as the broker and the remote server, a linux box, acts as the client.

When classical storage is considered, several alternatives are also possible,

- InfluxDB: It is a distributed and open source databse. Written in Go language and based on LevelDB. It is a database with structure of pairs key-value and gives an HTTP interface and libraries for the interaction with the users. It can be accesed via software like Grafana [7].
- MongoDB: It is an open source database, flexible and free. MongoDB adds dynamic padding to documents and pre-allocates data files to exchange additional usage space. Makes efficient RAM performance for caching and query correction for indexes. It supports an enriched query language to carry out read and write operations (CRUD), as well as data aggregation, text search and geospatial queries [8].
- MariaDB: is a popular fork of MySQL, created by the original MySQL developers. It offers support for both small data processing tasks and corporate environments. It offers the same MySQL features and many more. All MariaDB is under GPL, LGPL or BSD. It runs on virtually all operating systems and works under many programming languages. Offers support for PHP. It offers Galera cluster technology, which supports slave-master and master-master formats [9].

The classical storage of collected data at the remote implemented by using MariaDB, faces different risks, like data loss because of unavailability (shutdown, maintenance, etc.) of the database engine itself. Indeed, a major limitation is because querying such system will require to share the access to different users, and the stored data could be easily exposed to hackers.

An alternative, when the stakeholders are in a M2M environment and they can contribute to create a restricted blockchain based network, is to share all the relevant information among participants in a distributed database, where privacy is still granted between participants. It is important to note that the system is designed to build Blockchain networks among a series of previously specified parts that are known and trusted by each other. The process would be the following, a coordinating entity raises the first node and is the one that configures the adhesion of the rest of the nodes, knowing previously the public keys of those nodes. Therefore, available solutions can be found like BigchainDB: Broadly speaking BigchainDB is an open source software that has characteristics of both a Blockchain and a database. Launched for the first time in 2016, it is currently in the 2nd version that incorporates substantial advances with respect to the previous versions such as tolerance to Byzantine faults [10].

The Distributed Ledger technology and its characteristics and capabilities, which fit perfectly with the requirements of the application, are presented in the Table 1.

Table 1: Compared characteristics for data storage

	Tyìcal Blockchain	**Typical Distributed database**	**BigchainDB**
Descentralization	✓		✓
Tolerance to Bizantine faults	✓		✓
Inmutability	✓		✓
Assets Controlled by the Owners	✓		✓
High Throughput		✓	✓
Low Latency		✓	✓
Index and Query		✓	✓

When the business case requires to provide information to different stakeholders, including single individuals (final users for instance) with no IT resources compromised, a different solution could be convenient,

- <u>IOTA:</u> It is a state-of-the-art decentralized database, which uses a new technology called the Tangle as the operating core [11], [12]. This Tangle is a new data structure based on "Directed Acyclic Graph" (DAG). Because of this, it breaks the paradigm of the decentralized Blockchains existing up to now, since in this system allows there are no blocks, chains or miners. IOTA is one of the Blockchain technologies called third generation [13].
  IOTA completely revolutionizes the technology and the usability of the exchanged information. It is also possible to make transactions of value 0 iotas (the IOTA token) and therefore, the exchange of information between devices in a practically instantaneous, free and decentralized way.

III. PROPOSED FRAMEWORK

Once selected the most convenient technologies to be used in the adopted business case. Therefore, the general architecture of the proposed system can be found in Figure 1.

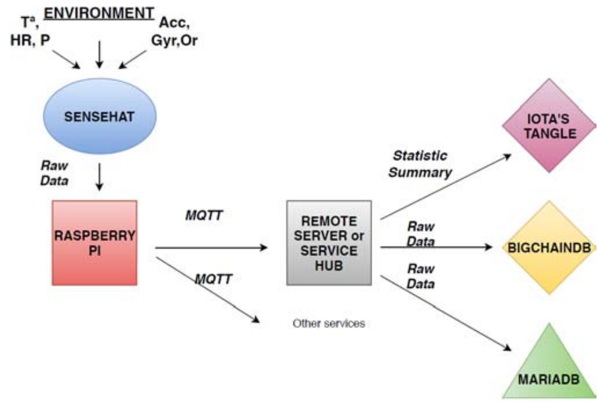

Figure 1.- Proposed framework, useful in different context of stakeholders.

The proposed framework allows implementing different configurations, starting at the smart sensor level, based on the Raspberry Pi, and sample code has been released over Github [14]. Therefore, in our implementation, we have adopted the Paho-mqtt python package, available for different platforms including Raspberry Pi [15]

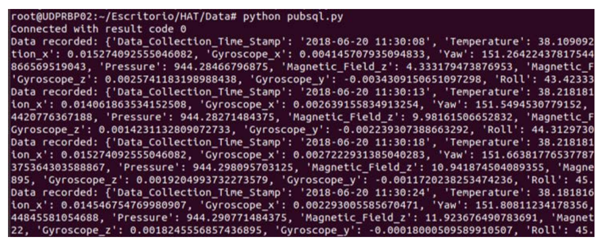

Figure 2.- Echo of the MQTT broker running at the Raspberry Pi.

Different clients can register their interest for news on specific topics. As for this implementation, we have defined just one channel named 'test/data' (see. Figure *2*). This architecture enables different clients register to receive such data streams, making it possible to have enough resilience in the data processing chain.

The remove clients are able to register and collect relevant data from sensors, see Figure *3*.

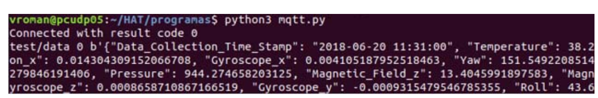

Figure 3.- Echo from a MQTT client receiving the subscribed data.

According to the interesting business model relevant to the application, different sharing mechanisms can be packaged to better serve the stakeholders. If the business model only requires internal data flow, the next steps can focus over a relational database into the organization's intranet, where trust is implemented through different mechanisms. This is the common configuration found in most of the cases.

When the benefits come from the data sharing from a few organizations related to the product's chain value, the most suitable information architecture can be to develop a BigchainDB decentralized database, where trust comes from the membership to the interested stakeholders. In the application case introduced at the beginning (distribution of frozen food), if the beneficial is to provide tracking to the different players in the value chain, the suggested solution would be the decentralized database (see Figure *4*).

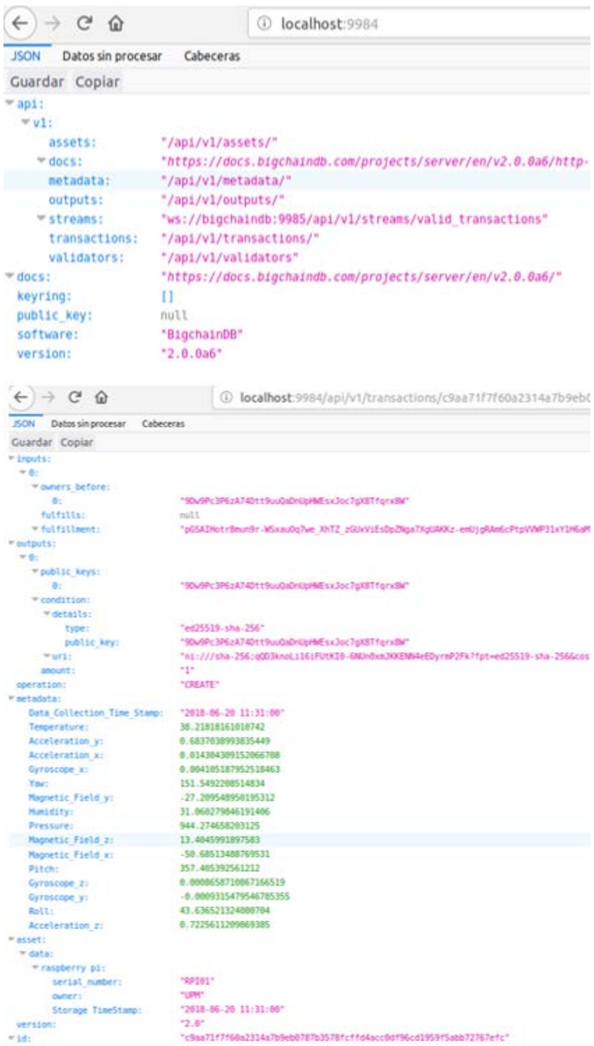

Figure 4.- BigchainDB configured to store and share the data among a limited number of stakeholders.

When the benefit in the business model requires the public to participate, in order to provide the convenient level of transparency, the approach should involve full public infrastructure, avoiding trust issues between participants and relaying on data immutability. The case will be when the customer of the frozen food wants to check the entire distribution process for a code based or anchor related piece of food. In this case the customer is interested in aggregated statistics certifying that physical parameters were all the time under the threshold.

The suitable configuration in such cases is to produce the statistical treatment summarizing the minimum, the maximum, the mean, the median as well as quartiles during a period of time, in our case every 15 minutes. Such information is encoded as trytes, because every IOTA message is limited to 81 trytes (2187 characters). After coding the message is sent to the tangle to become published. The required time depends on the intensity of actions but it rounds 10 seconds.

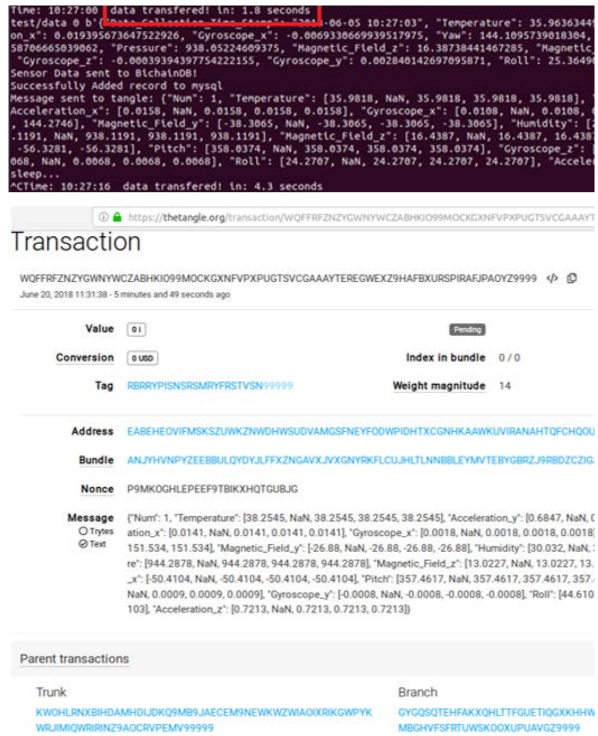

Figure 5.- Details of one of the IOTA transactions already processed by the tangle.

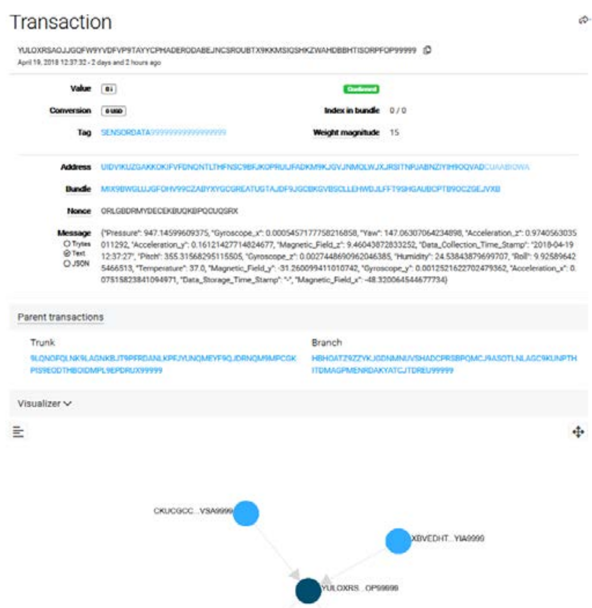

Figure 6.- Details of one of the IOTA transactions where the visualizer shows the validating transactions.

After getting the message published, any customer can access the data through the public tangle (https://thetangle.org) by using the tag as being referred to the code id or anchor reference (see Figure 5).

The implementation enables not only to access the data linked to the transaction, but also the sequence of transactions, as it can be seen at the bottom of the Figure 6.

Obviously, combination of technologies are also welcome depending of the situation. For instance, in the selected driven case, it could be a beneficial when value chain related companies need to have access to the specific data, including geolocation, etc., but still it does make full sense to keep the summary information available to the consumers, providing the proper level of transparency. If this is the case, the technical solution to be implemented shall be the BigchainDB as well as the summary service publishing through the tangle.

IV. CONCLUSIONS

The proposed framework enables different technical configurations that can be related to different requirements to be fulfill. Such requirements come from the adopted design for increasing the added value of the business, where added value can be physical value or transparency.

The implemented allows verifying the capabilities of such framework.

In the future, extensions of the IOTA to support additional references to large data streams will provide extended managerial capabilities, like those related to monetization of individual values for parameters when needed.

V. REFERENCES

[1] A. Preukschat, *Blockchain: la revolución industrial de internet*. Gestión 2000, 2017.

[2] K. Rong, G. Hu, Y. Lin, Y. Shi, and L. Guo, "Understanding Business Ecosystem Using a 6C Framework in Internet-of-Things-Based Sectors," *Int. J. Prod. Econ.*, vol. 159, pp. 41–55, Sep. 2014.

[3] Z. Shelby, K. Hartke, and C. Bormann, "The constrained application protocol (CoAP)," 2014.

[4] E. Avilés-López and J. Antonio García-Macías, "TinySOA: A service-oriented architecture for wireless sensor networks," *Serv. Oriented Comput. Appl.*, vol. 3, pp. 99–108, 2009.

[5] N. Hackius and M. Petersen, "Blockchain in logistics and supply chain: trick or treat?," in *Proceedings of the Hamburg International Conference of Logistics (HICL)*, 2017, pp. 3–18.

[6] U. Hunkeler, H. L. Truong, and A. Stanford-Clark, "MQTT-S—A publish/subscribe protocol for Wireless Sensor Networks," in *Communication systems software and middleware and workshops, 2008. comsware 2008. 3rd international conference on*, 2008, pp. 791–798.

[7] B. Balis, M. Bubak, D. Harezlak, P. Nowakowski, M. Pawlik, and B. Wilk, "Towards an operational database for real-time environmental monitoring and early warning systems," *Procedia Comput. Sci.*, vol. 108, pp. 2250–2259, 2017.

[8] E. Dede, M. Govindaraju, D. Gunter, R. S. Canon, and L. Ramakrishnan, "Performance evaluation of a mongodb and hadoop platform for scientific data analysis," in *Proceedings of the 4th ACM workshop on Scientific cloud computing*, 2013, pp. 13–20.

[9] B. Aditya and T. Juhana, "A high availability (HA) MariaDB Galera Cluster across data center with optimized WRR scheduling algorithm of LVS-TUN," in *Telecommunication Systems Services and Applications (TSSA), 2015 9th International Conference on*, 2015, pp. 1–5.

[10] B. GmbH, "BigchainDB: The blockchain database," no. May, pp. 1–14, 2018.

[11] M. Divya and N. B. Biradar, "IOTA-Next Generation Block chain," *Int. J. Eng. Comput. Sci.*, vol. 7, no. 04, pp. 23823–23826, 2018.

[12] IOTA Foundation, "IOTA Glossary." .

[13] A. Gaggioli, "Blockchain Technology: Living in a Decentralized Everything," *Cyberpsychology, Behav. Soc. Netw.*, vol. 21, no. 1, pp. 65–66, 2018.

[14] Victor Román, "GitHub - rromanss23/Store-Sensor-Data-in-BigchainDB-MariaDB-and-Publish-Statistic-Summary-to-IOTA-s-Tangle," 2018. [Online]. Available: https://github.com/rromanss23/Store-Sensor-Data-in-BigchainDB-MariaDB-and-Publish-Statistic-Summary-to-IOTA-s-Tangle. [Accessed: 20-Jul-2018].

[15] Roger Light, "paho-mqtt · PyPI." [Online]. Available: https://pypi.org/project/paho-mqtt/. [Accessed: 20-Jul-2018].