Iota vs. Ripple: A Comparison Inside An Economy of Things Architecture for Industry 4.0

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***Abstract*—The increase of the number and different types of devices within the Internet of Things context and the emergence of cryptocurrencies are bringing challenges, opportunities, and changes. How these technologies will impact the current business and economic models are still unknown. This work proposes an architecture aiming to use these new opportunities to enable the M2M interaction for Industry 4.0. Our work, used as base the novel paradigm called Economy of Things, focused on how to digitalize, monetize, and exchange assets inside the IoT context. An experimental environment was designed to explore and compare the characteristics of the cryptocurrencies Ripple and Iota. The initial results showed the Iota transaction time 9143% slower than Ripple and finished with a difference of 3707%. Also, while Ripple did not present transaction errors, in the last test configuration Iota had 4.3% of unconfirmed transactions, and 14.3% of requests needed to be resent. Although the Ripple network charges some fees, the cost to do 18,600 transactions was USD 0.05490. We considered it a small price to pay for a more stable network.**

I. Introduction

The significant increase in the number of devices on the Internet of Things (IoT) context and the emergence of the cryptocurrencies started to bring some opportunities. According to [13], the IoT will cause an economic impact in the next years, potentially changing some business models as we know nowadays. However, some challenges need to be solved first. Most of the IoT platforms were not made to integrate with others. It is a problem to join many communication patterns and try to use all as a unified system.

Some proposals are aiming to enable an environment inside an IoT context. The authors on [4] proposed a platform and API to connect different IoT systems. In [9], was proposed a marketplace using the data stored from IoT sensors. Furthermore, [7] proposed to use an approach for data publish/subscribe in order to enable the users to monetize their data.

The most proposals found are concerned about how to offer and consume services or data, focused on the platform users. Our work proposes a novel architecture that enables the same integration plus the possibility to remove or reduce as much as possible the human interference. Designed to be used on a machine-to-machine (M2M) interaction inside the Industry 4.0, our main contribution is an unprecedented comparison between two cryptocurrencies with potential to impact the current business models. Iota [8] was released, aiming to be the main IoT protocol and Ripple [2] to change the way we send assets around the world. Another contribution is our architecture that enables the use of multiple cryptocurrencies.

The structure of this work is organized as follows. The second section brings some relevant concepts related to the proposal. In the next section, we discussed some related works. In sections IV and V, our proposed architecture and the experimental environment are presented. In the next two sections, we discuss the results obtained, making a comparison between Ripple and Iota, and we talk about the challenges and drawbacks. Conclusions and future work are presented in section VIII.

II. Background

A. *Internet of Things (IoT)*

The interaction between devices connected to the Internet, where everything can be considered a distinct object, is called the Internet of Things (IoT). IoT objects can communicate with each other and even with users, to provide information and take decisions [1].

Sensors, actuators, and smartphones are some of the devices types. According to [3], the IoT concept is based on these smart things, pervasively distributed in an environment. IoT applications can be used in several areas such as health systems, smart homes, and industry, where it is called Industry 4.0 or Industrial IoT.

Although Industry 4.0 can be considered the future of the industry, there still exist some open research challenges, such as the development of smart devices, the construction of the

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network environment, big data analysis and processing, and digital production [15].

B. Cryptocurrencies

The concept of cryptocurrencies started between the years of 2008 and 2009 with the publication and development of Bitcoin [10]. Its work proposed to store data in a structure called blockchain, within a peer-to-peer system and with a consensus algorithm for assets exchange systems without intermediaries. With the popularization of Bitcoin, several other cryptocurrencies were released in the last years, such as Ripple, Iota, and Ethereum, implementing the concept of smart contracts that had already been proposed by [14].

1) Iota: Iota is a cryptocurrency created in 2015 to be used in IoT device's communication. Unlike most other currencies, it does not use blockchain for data storage. Instead, a network built on top of a directed acyclic graph (DAG) called Tangle [8] is used.

The main difference between a DAG and a blockchain is how the data is stored. Blockchain transactions are stored in blocks, and each block references the previous one. In the DAG, each transaction is stored directly, and to be able to store, it is necessary to confirm at least two existing transactions in the network, making the system scalable. According [11], the tangle will succeeds the blockchain as its next step, and offers the required features to machine-to-machine micropayment systems.

2) Ripple: According to [2], Ripple is a payment system and a cryptocurrency which was released completely independently of Bitcoin. Although Ripple used to be the second highest market cap after Bitcoin, there are no studies that analyze its provisions.

Different from the most other cryptocurrencies, Ripple is capable of performing cross-currency transactions in a matter of seconds for a small fee. Its transaction time turns itself an attractive technology to be used on economy domains, such as bank systems.

C. Economy of Things

Economy of Things (EoT) is a new paradigm for the exchange of digital assets. This name was first used by IBM©, in a report that highlights how Internet of Things has enabled digital markets [12]. According to the authors, although some assets have physical limitations for digitization, there are already opportunities for economic growth and advancement.

On [6], the authors explored the discussion about how the use of IoT together blockchains can create new opportunities in the shared economy area. They mentioned two projects: ExpressIT and Shared Things. The first one is an application focused on enable micropayments between IoT objects using a service-oriented approach. The second is a project about how to monetize shared economy applications. The site Slock.it© has some uses cases of EoT. As an example, it shows an application of how it is possible to pay and charge electric vehicles without third parties.

III. Related Work

The changes and impact from IoT and cryptocurrencies on the actual economic models are still unknown. In order to compare and validate our proposal, in this section, we present some related works.

Going trough on the potential economic changes caused by IoT, [13] offered an overview of an interoperable IoT ecosystem, analyzing potential business models. This work is part of BIG IoT project presented on [4]. According to the authors, each IoT platform defines its interface, data formats, and semantics. Furthermore, these characteristics are the main problem to have an IoT ecosystem. Some IoT standards were already proposed (eg. oneM2M [5]). The interoperability is needed to exploit economic impact, and it can bring new business opportunities for all participants. The authors also defined a Marketplace as the basis of such an ecosystem. This view follows the same idea proposed in our work, using a centralized Marketplace to publish and connect different providers and consumers.

On [4], the authors proposed the BIG IoT project. The goal is to build an IoT ecosystem aiming to enable cross-platform, cross-standard, and cross-domain IoT services interacting with each other. The proposal has as two main contributions, an API used for the IoT platforms and a Marketplace, where the IoT systems can act as applications to sell or buy services. Although the proposal seems to allow the interaction between IoT entities, our work goes beyond that, using the cryptocurrencies to enable the interaction without human interference.

Regarding a specific type of digital asset, [9] proposed a marketplace for IoT sensors data. The device owner can register his sensors along with standardized descriptions. So, the data consumers can query, define their criteria, and the available budget. The system finds the appropriate devices and provides the data on a mutual agreement. The data exchange on an IoT environment has a lot of specific characteristics, such as the quality of the data, the time when data was generated, among others. The solution proposed by the authors seems not fit to M2M IoT systems once it is not safe to configure devices to buy and sell data in an autonomous way. Despite the proposal of credibility criteria, it uses the rate of delivery measurements, but do not include the quality of generated data. We see the M2M as a natural evolution of the IoT ecosystem.

Aiming the Smart Communities systems, [7] proposed the marketplace I3. They used an approach where it is possible to publish and subscribe to data from IoT devices. The agreement occurs on an end-to-end way, between the device owner and the subscriber application developer. Similar to previous works, the proposal seems to work but does not enable M2M systems, since the focus from the proposal is on the agreement between the parties.

IV. Proposal

In order to enable M2M interaction inside the context of the Industry 4.0, we propose here an architecture aiming to remove or reduce as much as possible the human interference. Figure 1 shows the proposed architecture and its components.

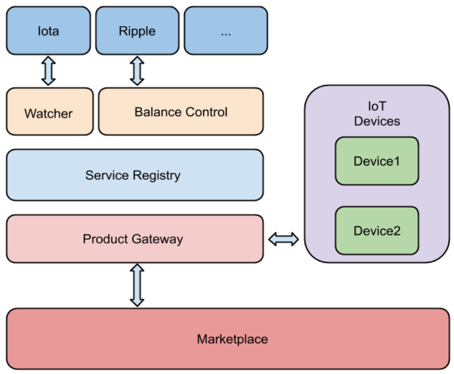

Fig. 1. Proposed Architecture.

All modules were figured out as independent components, resulting in an approach using microservices to reach out to the desired flexibility. We will go through each component to a better understanding of the proposal.

Service Registry: This module is responsible for register all microservices. With three different registration options (Service, Device, and Crypto), the service registry return the correct keys for each service based on the communication needed.

IoT Devices: The device represents a factory sector or an industrial process. Its role is to be responsible for informing whats it is producing, manage its stock, and, if needed, even be a client from the marketplace module, searching for products.

Product Gateway: Is responsible for registering all devices/products in the marketplace. This module acts over the IoT devices and manages all interactions. The requests for books, orders, and confirmations, will always be performed by this module. On our proposal, an intance of the proposed architecture can have only one product gateway, but several IoT devices representing different products.

Coin Gateways: The coin gateways are modules responsible for the communication with a specific cryptocurrency. As shown in Figure 1, we used two modules for communication with the Iota and Ripple networks.

Balance Control: Once we can use different one-to-many cryptocurrencies, the balance control was planned to abstract the communication with the coin gateways. This module makes every request to use funds from a currency.

Transaction Watcher: This is an asynchronous module with only one task. It monitors the confirmation of cryptocurrency transactions. When some transaction is done, the Watcher notifies the Product Gateway to confirm the order.

Marketplace: It was designed to be a place where several instances of the proposed architecture can register their devices, enabling a Provider/Consumer IoT ecosystem.

V. Experimental Environment

An experimental environment was designed aiming to test and compare the behavior of both cryptocurrencies used on our proposal. Figure 2 show how this environment was utilized in the tests.

The marketplace was placed on a Raspberry Pi 2. Its prototype was developed using the framework Flask for Python 3.6. As we just used it for the tests, it has only the endpoints *register* and *search*.

It was used a Raspberry Pi 2 together a Wemos D1 board to represent an instance of the proposed architecture. Almost all modules were developed using the framework Flask, except the Coin Gateway for Ripple, developed using Express.js and the device application, developed in C. Also, the prototype of the Product Gateway used an instance of the database MongoDB to register all orders.

Both Coin Gateways started the tests using the available test networks instead to configure and use a private node. For Iota, we need first to change the tests to the main network of the tangle and after change for a paid permanode, trying to avoid timeout and exceeded requests. We used the PyOTA library for Iota connections and ripple-lib for Ripple.

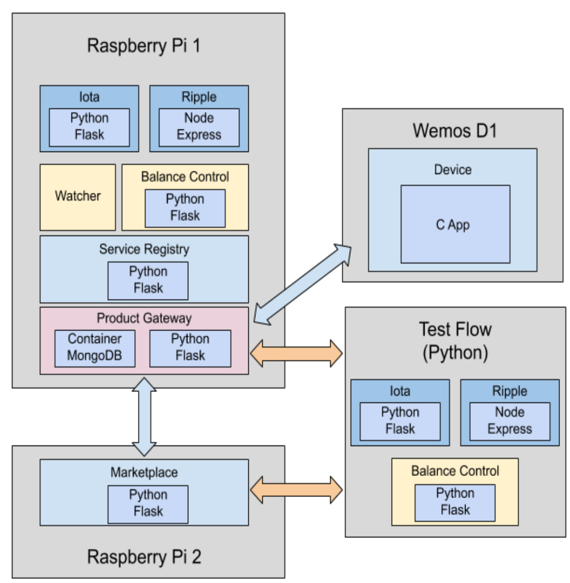

Fig. 2. Experimental Environment.

A Python script was used to perform the tests. The modules Balance Control and the gateways for Iota and Ripple were placed in a device in order to simulate potential buyers. The test started using one thread executing 100 times the flow shown in Figure 3. We incremented the number of threads, performing the tests with 5, 10, 25, 50, and 100 also.

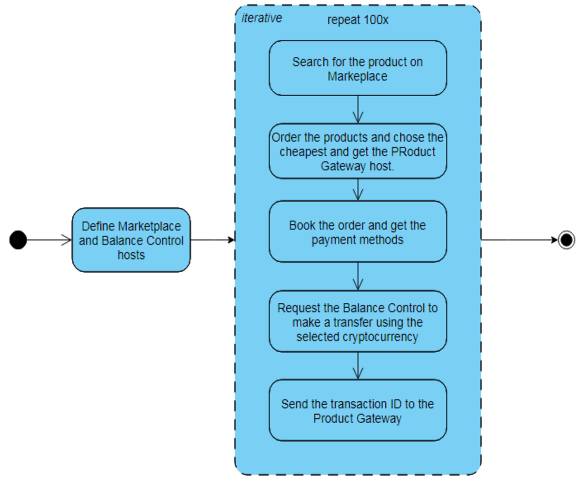

Fig. 3. Test Flow.

All executions were done first using only one currency and repeated to the other one. More than thirty-five thousand transactions were created in the process.

VI. Results

In order to a better understanding, this section will be splitted in three subsections, presenting first the individuals results obtained with each cryptocurrency and finishing with the comparison of both.

A. Iota

Figure 4 shows the metrics about the transaction time according to the number of threads used on the test. Although it is possible to see an increase between each test, the time growth does not follow the same proportion of the threads. The differences between the first and last tests were 296% for the average time, 418% for the minimum, and 430% for the maximum. The difference from the fastest transaction (1 thread) and the slowest one (100 threads) was almost 20 minutes (5900%).

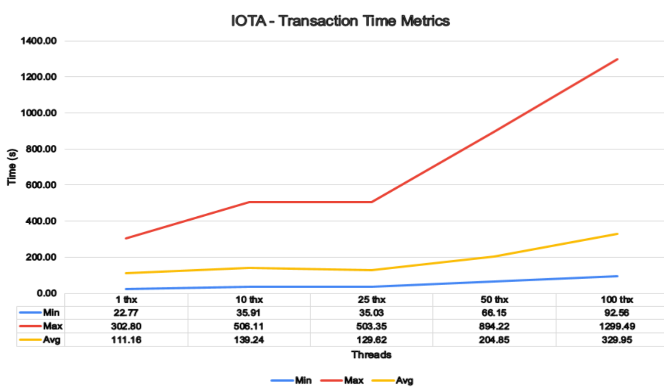

Fig. 4. Iota Time Metrics.

Going in-depth on the transaction time is possible to see in Figure 5 three well-formed paths over the 9570 valid transactions. The first and most dense path started with the values slightly lower than the average of 329 seconds and finished a bit higher. The second one started higher than the average, had some values lower but finished with more than double the value. The third and not so dense path started higher than the previous two but lost its density over the transactions. After 5000 transactions, it is possible to say we have only two paths.

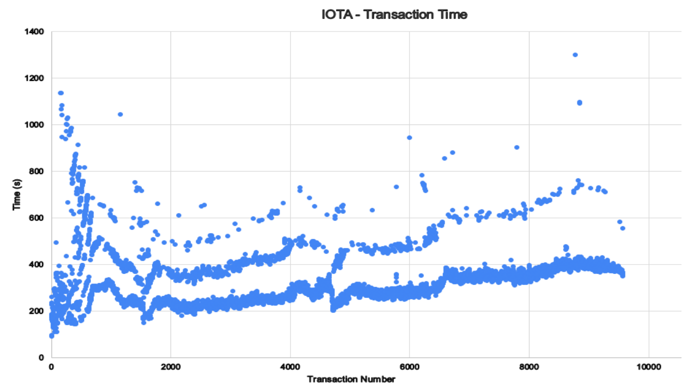

Fig. 5. Iota Transaction Time - 100 Threads.

TABLE I
Errors and Timeouts

	1 thread	10 threads	25 threads	50 threads	100 threads
Timeouts	0	13	19	173	430
Request Erros	0	3	152	617	1430

Over the threads increasing, the Iota network presented some instability. It is possible to see in Table I the number of requests errors and timeouts for each test configuration. The tests started with no errors and finished with 4.3% of unconfirmed transactions, and 14.30% of requests needed to be resent.

B. Ripple

It is possible to see in Figures 6 very stable values for both metrics of average and minimum time on the tests using the Ripple cryptocurrency. However, it is also possible to see a fast increase in the maximum transaction time over the 10000 transactions. The differences found between the first and last tests were 0.75% for the minimum time, 729% for the average time, and 17300% for the maximum time. It is important to highlight the value of the average metric. Looking at the chart for the first time, it seems much more stable than Iota. However, using the values, the difference is more than double.

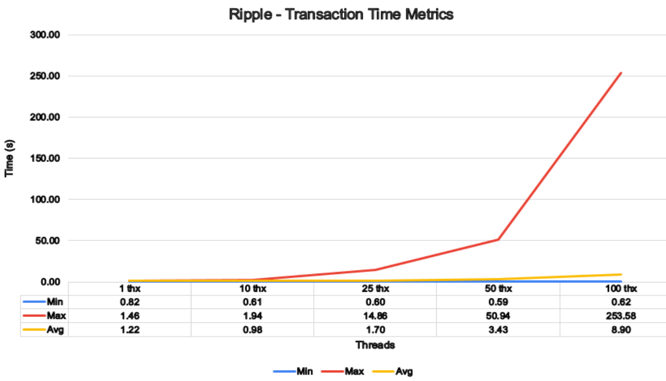

Fig. 6. Ripple Time Metrics.

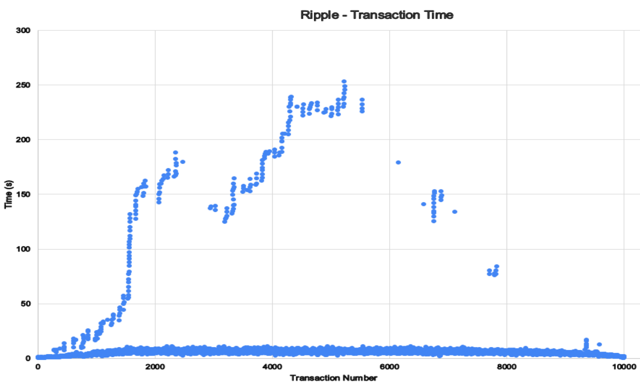

Fig. 7. Ripple Transaction Time - 100 Threads.

The values found on the Ripple transactions time (Figure 7) show a very different result than found with IOTA. We can see a very dense path under the line of 12 seconds, almost 3 seconds higher than the average. There exists another path, but after 5000 transactions, it starts to become small clusters instead of a path. After comparing both scatter plots is reasonable to affirm the Ripple as the most stable coin when we use the average transaction time to compare.

TABLE II
TRANSACTIONS FEES

	100 ts	1000 ts	2500 ts	5000 ts	10000 ts
XRP	0.0012	0.012	0.03	0.06	0.12
$ (1 XRP = 0.246)	0.000246	0.00246	0.00738	0.1476	0.02952

Table II[1] shows the fees applied to each test configuration. Although the Ripple network charges a variable fee, it is possible to see that the small value does not make its use unfeasible. For the tests, we got an average fee of 0.000012 XRP (USD 0.000002952). The total values spent on the tests was USD 0.05490 for 18600 transactions.

C. Iota X Ripple

Figure 8 shows a comparison between Ripple and Iota transactions times over the increasing on the number of threads. Starting with 9143%, the difference between the average time decreases (except with 10 threads) until the difference of 3707% with 100 threads.

[1]Conversion made using the site www.worldcoinindex.com

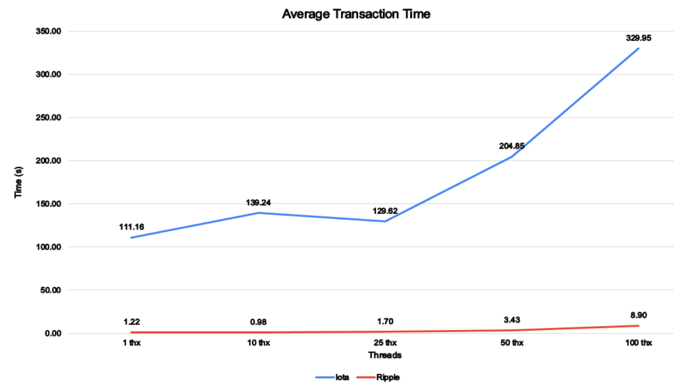

Fig. 8. Iota x Ripple: Average Transaction Time.

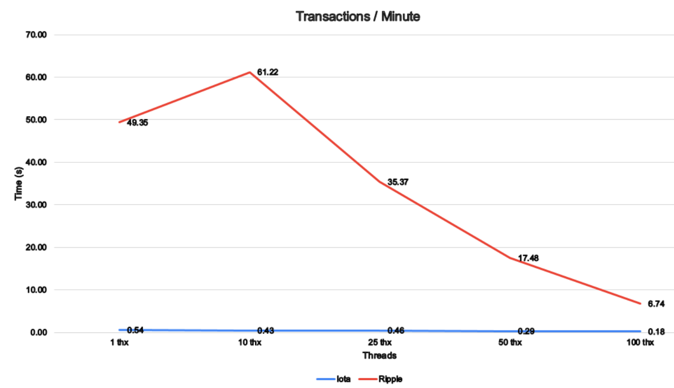

Fig. 9. Iota x Ripple: Transactions / Minute

Looking to the same information but differently, Figure 9 shows the transactions confirmed per minute of both cryptocurrencies. On the last graph, it is easier to see the difference decreasing over the tests. A surprising increase happened on Ripple tests with 10 threads, obtaining more than one transaction confirmed per second.

It is important to emphasize that we used an overdimensioned number of threads trying to simulate a real environment. It is unlikely to see 100 different devices doing 100 sequential orders for the same device. Maybe if we kept increasing the number of threads, we could have similar times on both currencies. Our concern is about how much time each transaction could take on this scenario.

VII. Challenges and Drawbacks

In this section, we will go through the challenges and drawbacks we had in our experimental environment to finish the tests.

A. Ripple

The first problems we had with Ripple network were the slow transactions loss of connection errors. At the tests with 1 thread, we had 9 seconds as the average time. This value is almost seven times higher than the final tests. To solve the problem, we started to reutilize the connection. We change from opening the connection on every request to a unique connection for all Express endpoints. After the changes, the average time decreased to 4 seconds.

We also had a problem with duplicated and invalid transactions. They were solved using a random value for the transaction and started to use different addresses on the Ripple network for each thread.

The most significative issue on Ripple was the problem of confirming the transactions after some time and some ledger version errors. To solve it, we started to use the status returned on the transaction as the confirmation status, creating a second and sequential confirmation step on the IoT device. With this last change, we reach out to the presented times.

B. Iota

Just like the Ripple, the first problem found on the Iota network was the slow requests on the network. We realized that maybe, the use of a fixed address could be the problem. First, we changed to generate a new address every transaction and then, we used a thread changing the addresses every 10 seconds.

After slow results and timeouts we changed the tests from the developer to the Main Iota network. However, for 50 and 100 threads, we started to exceed the requests allowed. So, we changed to a paid Permanode. It is important to highlight that we could set up our own node. We will not count the use of a paid node as a cost from the Iota network.

Doing the tests, we started to notice that some transactions were not confirmed. First, we tried to reduce the Proof-of-work complexity on the transaction. This solution started to create invalid transactions, so to solve the problem, we started to count any transaction that took more than 1 hour to confirm as a timeout.

VIII. Conclusion and Future Work

Our work presented an architecture aiming to enable the M2M interaction on Economy of Things environments, like an Industry 4.0. We performed some test cases to compare the characteristics of the cryptocurrencies Iota and Ripple. Both were chosen due to their primary goal, be an IoT protocol for Iota and fast assets exchange around the world for Ripple.

The tests were made using the coins isolated, performing 100 sequential requests per thread. We started with only 1 thread and repeated it for 10, 25, 50, and 100 threads also. At the end of the tests, more than 35,000 transactions were made.

Regarding the experiments, the initial results showed the Iota transaction time 9143% slower than the Ripple. After increasing the number of threads until 100, this difference decreased to 3707%. Also, Iota presented some instability over the tests. The number of timeouts (confirmation time higher than 1 hour) and request problems were increasing in a higher proportion than the threads. These numbers reach out to 4.3% of unconfirmed transactions, and 14.3% of requests resent.

Besides that, looking for the transaction time chart (Figures 7 and 5), it is possible to see that Ripple had a more stable "path" on the confirmation time. We conclude so that even charging some fees, the Ripple network has a higher potential to be used on IoT devices transactions. Taking into account the time rate and network stability, we can affirm that at least for now, the Ripple network is better qualified to be used on a real IoT ecosystem.

As future work, there is a need to continue testing other cryptocurrencies, trying to find the better option that fits with our requirements. Finally, the next goals are to go through the cryptocurrencies networks and try to use them as a communication way between the IoT devices.

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References

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash. Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communication Surveys & Tutorials.*, 2015.

[2] F. Armknecht, G. O. Karame, A. Mandal, F. Youssef, and E. Zenner. Ripple: Overview and outlook. In M. Conti, M. Schunter, and I. Askoxylakis, editors, *Trust and Trustworthy Computing*, pages 163–180, Cham, 2015. Springer International Publishing.

[3] L. Atzori, A. Iera, and G. Morabito. The internet of things: A survey. *Comput. Netw.*, 54(15):2787–2805, Oct. 2010.

[4] A. Bröring, S. Schmid, C. Schindhelm, A. Khelil, S. Käbisch, D. Kramer, D. Le Phuoc, J. Mitic, D. Anicic, and E. Teniente. Enabling iot ecosystems through platform interoperability. *IEEE Software*, 34(1):54–61, Jan 2017.

[5] S. K. Datta, A. Gyrard, C. Bonnet, and K. Boudaoud. onem2m architecture based user centric iot application development. In *2015 3rd International Conference on Future Internet of Things and Cloud*, pages 100–107, Aug 2015.

[6] S. Huckle, R. Bhattacharya, M. White, and N. Beloff. Internet of things, blockchain and shared economy applications. *Procedia Computer Science*, 98:461 – 466, 2016. The 7th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2016).

[7] B. Krishnamachari, J. Power, S. H. Kim, and C. Shahabi. I3: An iot marketplace for smart communities. In *Proceedings of the 16th Annual International Conference on Mobile Systems, Applications, and Services*, MobiSys '18, pages 498–499, New York, NY, USA, 2018. ACM.

[8] D. M and N. B. Biradar. Iota-next generation block chain. *International Journal of Engineering and Computer Science*, 7(04):23823–23826, Apr. 2018.

[9] K. Mišura and M. Žagar. Data marketplace for internet of things. In *2016 International Conference on Smart Systems and Technologies (SST)*, pages 255–260, Oct 2016.

[10] S. Nakamoto. Bitcoin: A peer-to-peer electronic cash system. https://bitcoin.org/bitcoin.pdf, 2008. Accessed: 11/02/2019.

[11] S. Popov. The tangle. version 1.4.3. https://www.iota.org/research/academic-papers, 2018. Accessed: 13/11/2019.

[12] V. Pureswaran and R. Lougee. The economy of things: Extracting new value from the internet of things. https://www.ibm.com/thought-leadership/institute-business-value/report/economyofthing, 2015. Accessed: 13/11/2019.

[13] W. Schladofsky, J. Mitic, A. P. Megner, C. Simonato, L. Gioppo, D. Leonardos, and A. Bröring. Business models for interoperable iot ecosystems. In *InterOSS@IoT*, 2016.

[14] N. Szabo. Formalizing and securing relationships on public networks. *First Monday*, 2(9), 1997.

[15] K. Zhou, Taigang Liu, and Lifeng Zhou. Industry 4.0: Towards future industrial opportunities and challenges. In *2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, pages 2147–2152, Aug 2015.