Green Efficiency for Quality Models in the Field of Cryptocurrency; IOTA Green Efficiency

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***Abstract*—In the last few years, cryptocurrencies have found a special place in the free economy. In addition to the importance and economic features of cryptocurrencies, the technical perspective on this area is also significant. If we want to use cryptocurrencies in the future as a global technology with everyday use, then this field needs to be optimized. In addition to issues such as security, scalability, speed, etc., energy efficiency and sustainability should also be considered.**

In this paper, the proposed "green efficiency" characteristic is added to the quality model for the field of cryptocurrency. This characteristic consists of four units that have independent tasks, the overall process of which seeks to design an optimal quality model in terms of energy consumption in cryptocurrency. The central unit of this proposal is the G-ECC, which controls other units. The unit makes the final decision to reduce energy consumption and trade-offs between features by reviewing and evaluating reports received from other units. At the end of this article, the green efficiency of IOTA cryptocurrency is reviewed in the proposed model.

Keywords— cryptocurrency, quality model, green efficiency, sustainability, energy consumption, IOTA

I. Introduction

The payment systems are an integral part of the economic cycle. Cryptocurrencies are designed for future payment systems [1] which will be used by new generations. Energy consumption is one of the primary factors that determine the green aspects of cryptocurrency as a popular currency.

Cryptocurrency technical approach requires a qualitative model to protect environment and evaluate the energy consumption of cryptocurrency. This paper proposed a basic green quality model and reviewed the green efficiency requirements for decentralized cryptocurrency.

While investigating cryptocurrencies generally, the paper proposes a green efficiency model for quality model and low energy consumption. It designs a simple macro model which easily illustrates the important issues of energy-wasting. This paper also presents a way to implement cryptocurrency in a green area. This version focuses on the green characteristic of the quality model; while other characteristics are not considered.

A. Cryptocurrency and its energy usage

Bitcoin [1] is a cryptocurrency designed to implement the Distributed Ledger Technology (DLT) on a global scale. The DLT aims to store valuable data in a decentralized network so that data is not stored centrally (in specific locations) [2], [3]. Today, cryptocurrencies have found a special place in public and specialized circles, and the culture of paying with cryptocurrencies is spreading. Bitcoin and some other cryptocurrencies use the Proof-of-Work (PoW) mechanism to ensure network security and stability. This mechanism requires a lot of processing power to solve computational puzzles, which must be done randomly by special computing machines [4]. The calculations have created a kind of contest in which participants are intended to find the correct answer for the prize. The calculations have significant global energy consumption associated with heat generation.

In fact, Bitcoin consumes enormous amount of energy with PoW mechanism; its quantity is the same as countries' energy consumption [5], [6]. [5], [7] and [8] focused on Bitcoin energy consumption and results show apparent energy wasting in Bitcoin mining; in [8], [9], and [10] it is tried to optimize and reduce energy consumption of PoW in the blockchain. In addition, in [11] it proposed a solution to use renewable energy for mining; on the other hand, the author of [12] says: even renewable energy will not solve Bitcoin's sustainability problem. Too much energy consumption of PoW causes the challenge in cryptocurrencies community while the phenomenon of Bitcoin energy usage is getting worse and worse.

Ethereum [13] is a cryptocurrency among top three cryptocurrencies based on market capitalization [14]. It has a PoW mechanism like Bitcoin; but their community decided to switch to Proof of Stake (PoS) with lower energy consumption and several other advantages [15]. This decision can show that energy consumption is one of the important issues in cryptocurrency communities.

The significant increase in CO_2 and electronic waste (e-waste) [12] are also among the important issues in the cryptocurrency industry which we do not address in this work-in-progress paper. But the issues will become much better if the proposed green efficiency model to be applied.

At the end of this article, IOTA [16] cryptocurrency was reviewed and its green efficiency was briefly stated.

B. A Brief History of Quality Models

Quality model is a tool to determine and evaluate the quality characteristics of software. In 1977, Jim McCall [17] introduced the quality model for system developers and the system development process. The McCall model seeks to establish a link between users and developers by defining a number of software quality factors that reflect both users' views and developers' priorities.

Another quality model is proposed by Barry W. Boehm [18]. The Bohem model tries to define the quality of the software suite with a specific set of attributes and metrics. Boehm's model presents a hierarchical quality model structuring high-level, intermediate level, and primitive characteristics.

In this article, the ISO/IEC 25010:2011 quality model [19] is more attention, which is an extended version of ISO/IEC 9126:2001 [20] to include computer systems and quality in use from a system perspective. The internal/external quality factors in ISO/IEC 9126 have been combined as the product quality factor in ISO/IEC 25010.

Security, which is an important feature of cryptocurrency, is also known as sub-characteristics in ISO/IEC 9126 as characteristics in ISO/IEC 25010, which itself includes separate sub-characteristics of Confidentiality, Integrity, Non-Repudiation, Accountability, and Authenticity. And Compatibility has been added to the model as a new characteristic, which includes sub-characteristics of Coexistence and Interoperability.

ISO/IEC 25010 has eight characteristics, which has two more characteristics than ISO/IEC 9126; Table I shows all the characteristics and sub-characteristics of this model. It is noteworthy that the ISO/IEC 25030 [21] standard, which was published in 2019 to standardize quality requirements, still refers to the ISO/IEC 25010 quality model and no change has been considered for it. Due to the comprehensiveness of the characteristics of the ISO/IEC 25010 model, this model can be considered as one of the important candidates of the quality model for the cryptocurrency field.

TABLE I. EXTERNAL / INTERNAL QUALITY MODEL (ISO/IEC 25010)

Characteristic	**Sub characteristics**
Functional suitability	Functional completeness, functional correctness, functional appropriateness
Reliability	Maturity, availability, fault tolerance, recoverability
Usability	Appropriateness recognizability, learnability, operability, user error protection, user interface aesthetics, accessibility
Performance efficiency	Time behavior, resource utilization, capacity
Maintainability	Modularity, reusability, analyzability, modifiability, testability
Portability	Adaptability, installability, replaceability
Security	Confidentiality, integrity, non-repudiation, accountability, authenticity
Compatibility	Coexistence, interoperability

II. PROPOSED GREEN EFFICIENCY MODEL AND REQUIREMENTS

One One of the most useful system quality models for software quality model and engineering requirements is the Systems and software Quality Requirements and Evaluation (SQuaRE) ISO/IEC 25010 standard and ISO/IEC 25030 standard that focused on quality requirements. Nowadays, sustainability is a primary factor that should be considered in the software quality models [22]. Unfortunately, in both standards sustainability and green efficiency have not been considered. However, [23] added sustainability to ISO/IEC 25010 by deriving software sustainability assets.

This article tries to define green efficiency to be used in the early stages of designing and creating a global cryptocurrency. Keep in mind that trade-off between different characteristics is important, but this research paper, which has not yet been completed, has only a macro look at the proposed green quality model for the cryptocurrency domain.

This article does not focus on any of the quality models and only suggests green efficiency characteristic for the cryptocurrency field; because each cryptocurrency may be evaluated with any of the existing quality models. This article does not aim to add a specific characteristic to a particular quality model; rather, it just focuses on how to earn green efficiency in cryptocurrency, which can be added to any quality model.

The effectiveness of the defined green quality model for cryptocurrencies is variable depending on the nature of the five issues; (1) Distributed Ledger Technology (DLT) type, (2) Consensus Protocol (CP), (3) the implementation techniques and design of core, (4) the configuration of the hardware used to run the core and (5) green efficiency awareness.

These five items are considered in the four operational units shown in Figure 1 which proposed cryptocurrency green efficiency model in macro scheme. Figure 1 shows the relationship among these four units in such a way that each unit is related to its neighbor. At the center of the proposed model is the G-ECC unit, which communicates with other units because it performs the task of decision-making and control. All tasks of G-ECC unit are described in section II-D.

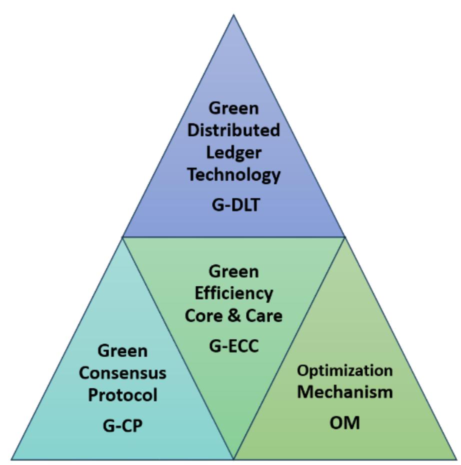

Fig. 1. Proposed Cryptocurrency Green Efficiency Model

Fig. 2 shows the steps of the selections and process of the proposed model with directional arrows and listed some of the selection candidates.

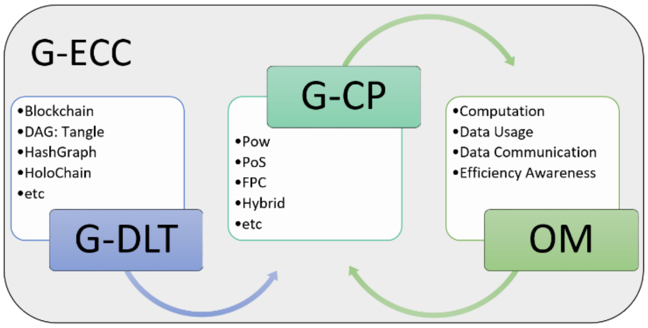

Fig. 2. Selections and Process of Proposed Green Efficiency Model

A. *Green Distributed Ledger Technology (G-DLT)*

DLT is the most well-known technology for cryptocurrencies, but the technology itself can be set up in more than one way. According to [24], the most notable features of distributed ledgers are immutability, decentralized maintenance, resistance to censorship, elimination of the need for a trusted third party and G-DLT tries to add the green vision to distributed ledgers' features.

There are several types of DLT that have different features. [24], [25], and [26] explain and compare notable DLT types by focusing on features. Authors of [27] and [28] explain the details of DLT as shows in Table II.

TABLE II. DISTRIBUTED LEDGER TECHNOLOGY SYSTEM LAYERS [28] AND ACTORS [27]

DLT System Layers	
Protocol	Consists of the core software that make up a distributed ledger
Network	Consists of the actual P2P network built on top of an existing protocol that brings the distributed ledger 'to life'
Application	Consists of all applications that are built on existing distributed ledger networks
Other	Data layer, Consensus layer, Ledger topology layer, Incentive layer, Privacy layer and Contract layer
DLT Actors	
Software services, Infrastructure provider, Application developer, Operator, Public sector institution	

G-DLT is placed at the top of the proposed model and the location shows the importance of this selection. Green efficiency of DLT type is the first challenge of G-ECC unit and duty of G-DLT unit is reporting all results and challenges to G-ECC unit. According to the proposed model, if we want to create green cryptocurrency, the green criterion should be considered in all parts of the Table II. Green steps are started with the nature of the DLT type features. The following Yes/No question must be answered before creating any universal cryptocurrency:

Is selected DLT type, flexible to and able to create an optimal cryptocurrency in energy usage?

Energy consumption is a significant item for optimal cryptocurrency and this is one of the questions that must be answered if we like to have green cryptocurrency. One should note that the platforms (e.g. Ethereum, Qtum, Waves, and etc.) are a subcategory of the G-DLT for creating the token.

B. *Green Consensus Protocol (G-CP)*

A large number of approaches for the consensus protocol have been proposed, each providing distinctive features, advantages and disadvantages [29]. For instance, blockchain with PoW protocol wastes an enormous amount of energy [30] and requires mining equipment [8]. The equipment generates heat like a heater and needs a cooling system.

Authors in [31], [32], and [3] broadly classify consensus protocol as lottery-based and voting-based. Lottery-based approaches include PoW public blockchains which are used by most cryptocurrency systems, such as Bitcoin or Ethereum. Moreover, another alternative is PoS which validators are selected either randomly or through a round robin algorithm, but imperatively the number of the "vote" of each validator depends on the amount of "stake" in the system [29]. PoS can potentially results to faster blockchain [33] which has much lower electricity consumption [29]. However, some complex consensus mechanism fit into both above categories. In addition, it is able to combine consensus protocols with each other to generate the Hybrid consensus protocols. For instance, Proof-of-Activity (PoA) mechanism [32] which uses PoW to create empty blocks, verify blocks and add transactions with PoS.

In the article [34], a standard has been set for the amount of energy consumption, to which has been assigned a degree for each amount of energy consumed in the transaction by cryptocurrencies. And the basis of energy consumption per transaction is the amount of energy consumption per transaction in global payment systems such as Visa and MasterCard.

In [30], authors explained several consensus protocols focusing on PoS consensus mechanisms and comparing them in some features, such as energy consumption. According to [30], energy consumption of PoS mechanisms is significantly reduced comparing to PoW mechanism as well as the energy consumption of PoW, Hybrid and PoS (all notable protocols: Ouroboros, Chains-of-Activity, Casper, Algorand and Tendermint) as in the following relation:

$$PoW > Hybrid\ (as\ PoA) > PoS$$

Having studied 140 blockchain initiatives in the energy sector and tracked a large number of research institutions, companies and startups, [29] authors classified blockchain using cases in the energy sector according to consensus protocol. Fig. 3 shows more than fifty percent of the studied projects wasted energy with PoW.

Green efficiency of consensus mechanism is the second challenge of G-ECC unit. G-CP unit should implement a new or the selected notable consensus protocol which has acceptable results for green efficiency (especially energy consumption).

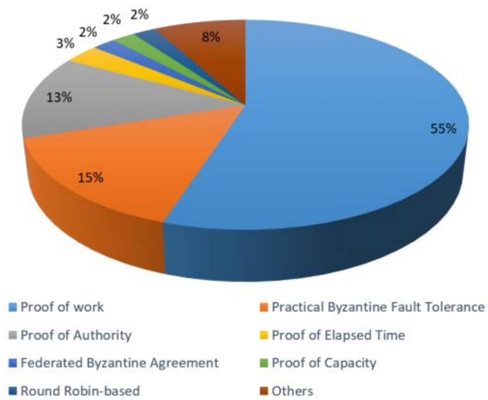

Fig. 3. BlockChain Using Cases in the Energy Sector according to Consensus Algorithm [29]

According to the proposed model, G-CP unit has a reverse relation from Optimization Mechanism (OM) unit, which reason is OM reports to G-ECC to optimize a part or all of the consensus protocol.

C. *Optimization Mechanism (OM)*

Energy efficiency of small devices up to powerful servers and also network architecture is significantly related to software behavior [35], [23]. Cryptocurrencies have special software part that runs in node which is called "core".

Based on [35] categorization of the optimization techniques, computation efficiency, data efficiency, and context awareness are main green techniques to optimize the energy consumption of the implemented. We revise this categorization for cryptocurrency scale, our view is close to [36] derived the corresponding sub-characteristics of the green efficiency characteristic. Fig. 4 shows new revise of green requirements associated metrics.

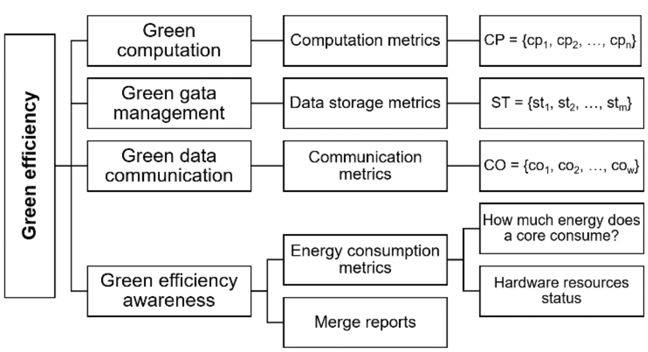

Fig. 4. A Revised View for [36] Green Requirements Associated Metrics

This paper proposes four sub-characteristics for cryptocurrencies' core optimization: (1) green computation, (2) green data management, (3) green data communication, and (4) green efficiency awareness. The first three sub-characteristics overcome the green efficiency issues at the computation, communication, and storage levels of the core of the cryptocurrency. The fourth sub-characteristic provides a descriptive behavioral energy consumption awareness chart and receives reports from the three listed sub-characteristic.

- **Green computation:** Reports the ability of the core to process the requests efficiently and may analyze PoW function by consuming an optimal amount of energy in the node.
- **Green data management:** Reports the effectiveness of the implemented data management strategies to perform I/O operations.
- **Green data communication:** Reports the efficiency of energy management policies when the core sends and receives data over the network.
- **Green Efficiency Awareness (GEA):** Software plays a primary role in overall platform energy efficiency and the infrastructure of green information technology is incomplete without energy-aware software [35]. This sub-characteristic is in parallel process with the core and is related to G-ECC directly. This sub-characteristic describes the whole energy consumption of the core in order to determine the different consumption levels and to define the expected behavioral of the core at the peak, the average, and low energy usage. Green-efficiency-awareness is a separate process which possibly needs optimization for itself and this task is in G-ECC role list.

In addition to the above components, there are other factors to assess the energy consumption in the core, such as the hardware configuration, the architecture design and the load balance of the network. OM unit's report with G-ECC decision-making role can optimize the consensus protocol, network load balancing, CPU usage, data storage and communication. We need to define the metrics of each component for measurement to achieve optimal goals as in Fig. 4.

D. *Green Efficiency Core & Care (G-ECC)*

G-ECC is a live unit to make decision and control the green efficiency of the cryptocurrency. This unit compares reports received from other units. Results of this analysis possibly change the technical mechanisms and relations.

a) Green Efficiency Core

This sub-unit manages all reports sent from all other units and sub-units, such as; G-DLT, G-CP, OM, GEA and Green Efficiency Care. Particular emphasis must be on the cryptocurrency core green quality analysis and evaluation. Based on [37] typical spiral model of the software, we presented a revised model for the green cryptocurrency core life cycle in Fig. 5 which includes the involvement of green constraints in the different region. The model enhances the green aspects of the core in every iteration of the macro-simple-spiral model.

Green Efficiency Core works as the same as a committee to choose the best option and all received reports help this sub-unit along this path. All decisions are made according to received reports; thus, all units must be careful to produce correct and accurate reports.

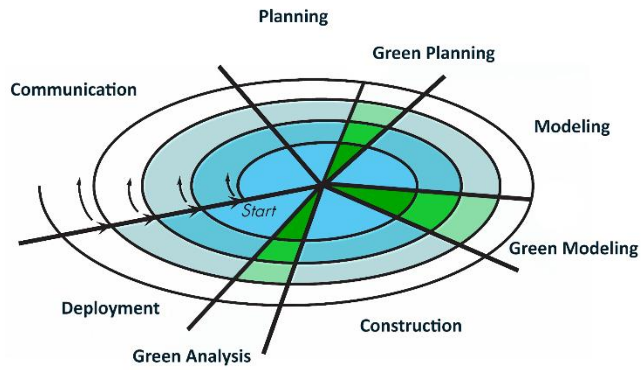

Fig. 5. Green Macro-Simple-Spiral Core Development Model

b) Green Efficiency Care

Keeping cryptocurrency in the green area is important. The green cryptocurrency development life cycle involves several sequentially related activities and this step should care about all cryptocurrency activities in green. In this step, there are two sections;

- **Green Protocol:** This section tries to growth saving energy consumption with several green protocols. Research team periodically processes the green protocols because some of the Green Requirements may change or modify. This section defines the green protocol for all parts of the model. It means that "How much energy each sector should consume?"
- **Green Controller:** This section tries to analyze the green efficiency of cryptocurrency with measuring tools and special metrics. If a part of the grid does a lot of energy dissipation, the alert and report will be sent to the Green Efficiency Core.

III. IOTA Green Efficiency

A. *IOTA and Tangle*

IOTA [16] cryptocurrency has no transaction fees and without fees allows the transfer of any amount of assets. IOTA is aiming the IOT industry so that machines can pay easily. There is no block, chain and mining in the IOTA network because the DLT is of a Tangle [38] type. The Tangle is based on DAG, of which IOTA is the most important program to run [39]. According to authors of [40], Tangle has a high throughput and scalability for IOT projects that generate large amounts of data.

Tangle needs a rate control mechanism to ensure that it does not exceed the maximum network capacity [41]. In the current state of the IOTA network, rate control is performed by the PoW mechanism, which calculates this mechanism locally on the user's device or on one of the network nodes to which the user is connected. However, in the IOTA ecosystem, a project called POWSRV [42] has been run to provide PoW as a service based calculation results for ease of transactions in systems with limited resources.

According to the IOTA roadmap in the IOTA 2 project, known as Coordicide [43], the rate control mechanism in IOTA is likely to change. It is noteworthy that in August 2020, IOTA successfully deployed the first phase of IOTA 1.5 known as Chrysalis to Mainnet [44]. Table III describes the IOTA 2 modules.

TABLE III. Module of IOTA Coordicide Solution [43]

Module	Description
Node Identities	Build a reputation and help secure the network by being a good actor.
Auto-Peering	Connect to the network automatically, simplifying node setup and maintenance.
Spam Protection	Enables low-powered IoT devices to access the network through an adaptive rate control mechanism.
Shimmer	The revolutionary voting module reaches a consensus in seconds. By leveraging proactive communication in the network it enables near-instant irreversible transactions.
Tip Selection	An optimized tip selection algorithm improves confirmation times and ensures transaction confirmation.

B. *IOTA Green Efficiency in the Proposed Model*

According to the IOTA Foundation, the IOTA network using Tangle for implementation is not yet complete and is looking forward to significant changes in the future.

In the current IOTA network, the coordinator periodically generates milestones to refer to valid transactions and also to protect the IOTA network from specific attacks. Having its coordinator and PoW mechanism at the origin of the transaction, IOTA has a sustainable network that intends to increase sustainability with decreasing message complexity and decreasing PoW in its new consensus protocol called Fast Probabilistic Consensus (FPC) [45].

The PoW used in IOTA may be confused with the PoW used in Bitcoin or Ethereum, but it should be noted that the energy consumption for PoW in the IOTA network is very light and is done by the origin of the transaction and not by the miners competing to create a new block; because IOTA network does not have inherently mining. In [34] the energy consumption of IOTA PoW is measured in the current network and according to the measurements, an average of 0.00016 kWh is consumed for each transaction in IOTA PoW; that is if MasterCard consumes an average of 0.0007 kWh of energy per transaction [46], which is more than 4 times.

In order to expand its network, IOTA has designed a lightweight node called Hornet [47] so that small computers and embedded systems can also function as nodes in the IOTA network. The IOTA Ecosystem also defines a project called Green IOTA [48] to measure grid energy consumption and monitor IOTA energy consumption.

Figure 6 shows the current IOTA grid view in the model proposed in this paper, where each unit of the model tries to optimize energy consumption. Due to the forthcoming IOTA 2, the model can be used to improve the sustainability in the IOTA network.

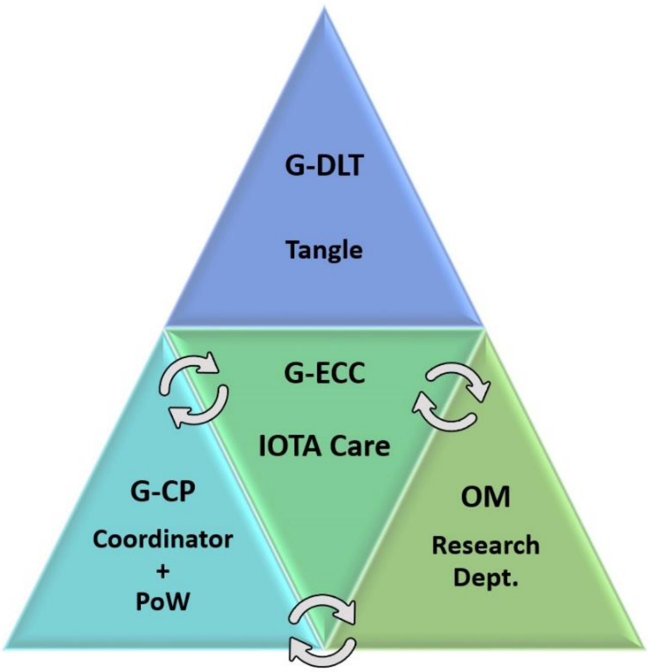

Fig. 6. IOTA Green Efficiency Model Based on the Proposed Model

As shown in Figure 6, 'IOTA Care' is responsible for the G-ECC, which should review the reports and documentation of the OM and G-CP units to not to conflict with the goals of Tangle and reducing energy consumption. The IOTA Care unit is a set of controllers and protocols that dynamically seek to strengthen network goals and green efficiency.

Research Department of the IOTA Foundation may be responsible for the OM unit, one of whose tasks is to optimize the various parts of the network in terms of energy consumption. According to the documentation in [49], IOTA is looking to change its protocol consensus, one of the results of which is to reduce the PoW to increase the sustainability in the network. This change of sustainability can be considered as the result of the research of the OM unit, which by sending its reports to the IOTA Care unit, was able to reach a consensus protocol that leads to more green efficiency.

IV. Conclusion and Future Work

In this work-in-progress article, we proposed macro green efficiency for quality model and its requirements for cryptocurrency. This model has four primary units and several sub-units. G-DLT unit choose best DLT in energy consumption and G-CP unit reports the best choices of consensus protocol to G-ECC for a final decision. Another unit called OM has several sub-characteristics to optimize the cryptocurrency technical approach. Main sub-unit of OM unit is GEA which merge reports and send them to G-ECC. G-ECC controls the green efficiency of cryptocurrency according to received reports. At the end of the article, IOTA cryptocurrency was presented in a proposed model to increase green efficiency, which had good results.

In future work, we will explain more details about all units and sub-units of the proposed model and suggest several ways to have green cryptocurrencies.

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