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METHODOLOGY FOR DEVELOPING AN IOT-BASED PARKING SPACE COUNTER SYSTEM USING XNO

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Abstract. The Blockchain-IoT integration is treated as the future technological value by many adopters despite the cost or complexity involved. But, there are technological advancements brought in by communities that make solutions affordable and simple to the fact that they can be used in applications such as parking space counters. This research portrays use of XNO which is a digital currency in an alternative way to keep track of available parking spaces via IoT nodes installed at entry and exit points of parking lots. The available parking spaces data using this approach can be displayed on LED boards at the entry point of the parking lots and on a website for remote status view. An add-on for this research is the issue of entry tickets with timestamp and unique ID by using the block data during asset transfer. This research can be further enhanced for collection of parking fees by the help of IoT nodes at the exit points of the parking lots.

Key words: IoT, Block-chain, Block-lattice, Energy-efficient, Sensors, Cryptocurrency, Parking Space Counter.

AMS subject classifications. 11U99, 11Y55, 11Z05, 28E99, 28A99

1. Introduction.

The origin of IoT dates back decades in comparison with Blockchain being coined. Long story short Tab.1.1 shows the historical technological evolution that brought in IoT and Blockchain.

Bitcoin was the first application of blockchain but unfortunately as Bitcoin matured several issues in the protocol made Bitcoin prohibitive for many applications which include: Poor scalability, High latency, Power inefficient. In 2012 an alternative consensus protocol, Proof of Stake (PoS) [12], was first introduced by Peercoin. PoS does away with the wasteful computation power competition, only requiring light-weight software running on low power hardware. Further enhancements were made when the first Directed Acyclic Graph (DAG) based cryptocurrencies [13] [14] [15] broke the blockchain mold improving system performance and security using a consensus system that provides quicker, more deterministic transactions while still maintaining a strong decentralized system. Meanwhile IoT had its own enhancements in 2014, Constrained Application Protocol (CoAP) [IETF RFC 7252] for low-power, lossy) networks over UDP was introduced [16].

In order to understand the value of the modern blockchain-based solutions one should refer to the traditional method of data collection from IoT nodes by a centralized database server as shown in Fig.1.1 which also handles multiple user requests which could lead to SPOF(Single Point of Failure).

In the world of IoT applications parking systems also have a considerable market share due to growing population, vehicles and traffic. George Mason University in Fairfax, VA, faced a parking deficit due to growth forecasts and to address this, a system was designed [17] to identify commuter populations, predict ridership, and analyze utility of shuttle routes or garages as the goal is to reduce traffic congestion and emissions, ultimately

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Nano(XNO) is a cryptocurrency launched in October 2015 by Colin LeMahieu to address the Bitcoin scalability problem.

Table 1.1: A history of events that lead to the IoT-Blockchain integration.

Year	**Event**
1954	Birth of the transistor-based electronic computer [1]
1969	ARPANET(Advanced Research Projects Agency Network) [2] was the first wide-area public packet-switched computer network to implement the TCP/IP protocol suite developed by DARPA (Defense Advanced Research Projects Agency) for academic and research purposes. ARPANET was decommissioned in 1989 and paved the way for modern internet.
1982	A beverage machine [3] connected via the internet at Carnegie Mellon University's School of Computer Science in Pittsburgh to remotely check if the machine was loaded with cold coke. The first IoT sensor data broadcast.
1982	Cryptographer David Chaum first proposed a blockchain-like protocol [4].
1990	A Sunbeam Deluxe Automatic Radiant Control Toaster was connected to the Internet [5], becoming the hit of the 1990 Interop. The first remote controlled actuator in IoT.
1991	Work on a cryptographically secured chain of blocks was described by Stuart Haber and W. Scott Stornetta [6].
1993	In 1992, Haber, Stornetta, and Dave Bayer incorporated Merkle trees into the design [7], which improved its efficiency by allowing several document certificates to be collected into one block.
1999	A British technology pioneer Kevin Ashton, co-founder of the Auto-ID Laboratory at MIT coined the term "The Internet of Things" [8] to describe a system where the Internet is connected to the physical world via ubiquitous sensors including RFID (Radio-Frequency IDentification).
1999	MQTT (Message Queue Telemetry Transport) a lightweight protocol over TCP suitable for IoT. MQTT is an OASIS standard and an ISO recommendation (ISO/IEC 20922) [9].
2008	Bitcoin: A chain of hash-based proof-of-work cryptocurrency [10] which popularized the application of Blockchain [11].

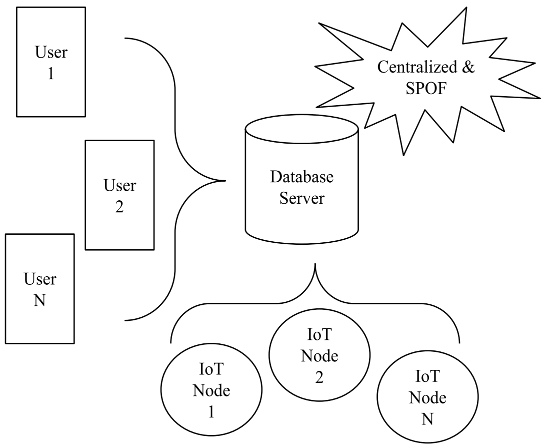

Fig. 1.1: A scenario of a traditional system handling requests from both IoT nodes and end-users which could lead to issues with centralization and SPOF.

ensuring sustainable growth. Similarly an image-based system for detecting vacant spaces in parking areas, combining edge density, closed contour density, and foreground/background pixel ratio for robust detection at low computational cost was proposed [18]. Later many researches have proposed different methods [19, 20, 21, 22] in order to address this parking space problem.

While IoT was bringing the physical things into the digital world, its architectural model as shown in Fig.1.1 had centralization leading to a SPOF(Single Point of Failure), Blockchain technology eliminated the

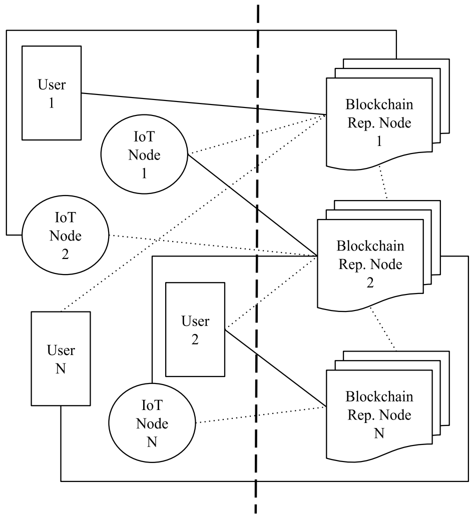

Fig. 2.1: A simplified decentralized architecture of using modern blockchains with IoT where requests from any entity are handled by various blockchain representative nodes and avoiding SPOF.

middleman for authoring or confirming a transaction. The integration of these two technologies was a need for a new breed of advancements.

2. Literature Survey. In 2015, an IoT electric business model based on the protocol of Bitcoin [23] was showcased which leverages blockchain technology and smart devices to revolutionize the energy sector. It enables seamless peer-to-peer energy trading, ensuring efficient utilization of renewable energy sources. IoT devices, like smart meters, monitor consumption, and autonomously interact with the blockchain, executing secure, transparent, and tamper-resistant transactions. Consumers can buy and sell excess electricity directly from one another, incentivizing green energy production and reducing dependency on traditional energy providers. The decentralized nature of the model as shown in Fig.2.1 eliminates intermediaries, reduces costs, and empowers individuals to participate actively in the sustainable energy economy. This innovation paves the way for a greener, more equitable energy future.

Securing smart cities using blockchain technology [24] offers a transformative approach to urban safety and efficiency. Blockchain's decentralized and immutable nature enhances data integrity, thwarting cyber threats and ensuring privacy in interconnected systems. Through tamper-resistant ledgers, critical infrastructure like transportation, energy, and healthcare can be safeguarded from unauthorized access and attacks. Smart contracts [25] can automate enforcement of regulations, streamlining governance and reducing corruption risks. Furthermore, blockchain's ability to facilitate secure peer-to-peer transactions fosters trust in smart city ecosystems, promoting seamless interactions between citizens, businesses, and government entities. Implementing blockchain-based solutions [26] [27] [28] can fortify smart cities against cyber threats [34], elevate citizen trust, and pave the way for a more sustainable and secure urban future.

Researchers started exploring the potential of blockchain for decentralized IoT [29] [30] architectures and discussed how blockchain could enhance trust, data integrity, and authentication in IoT networks. Blockchain-based solutions for IoT [31] device identity, access control, and data provenance gained attention leading to new consensus algorithms to handle the scalability challenges of combining IoT and blockchain. Integration of blockchain and IoT shifted towards energy management, supply chain, and smart city applications highlighting the potential benefits [32] of combining the blockchain's decentralized nature with IoT's data collection capabilities. Focus on blockchain-based solutions for securing IoT communications and enabling interoperability between devices explored the use of smart contracts to automate transactions and enforce rules [33] in IoT ecosystems. Continued research on blockchain's role in securing IoT data, improving trust, and addressing

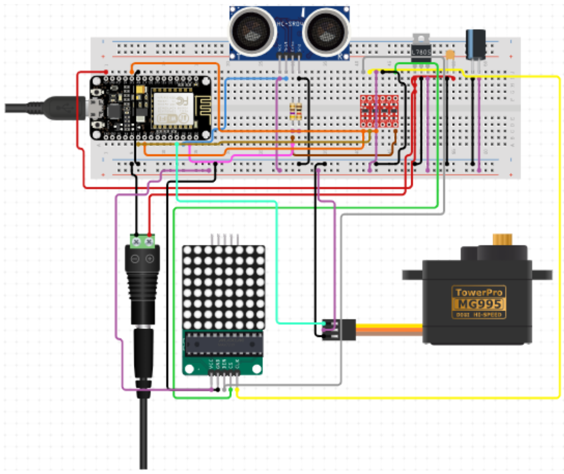

Fig. 3.1: Electronic design of the various components interconnected for a single IoT node in order to work with the proposed methodology at the entry/exit of the parking space

privacy concerns [35] discussed the challenges [36] [37] of integrating IoT devices with blockchain networks, such as resource constraints and high transaction costs.

Many advancements in parking space systems using computer vision & LoRa [38], AVI tags & RFIDs [39], transfer learning & deep learning [40] and Blockchain-IoT integration [41] [42] have bridged the gap between the needs of various solutions as the requirements change based on a problem being addressed. Hence, there is also a need to solve simple problems in Blockchain-IoT integration using economical and simple solutions which was taken up by this research and is proved by applying the methodology to a parking space counter.

3. System Architecture. The proposed system architecture as shown in Fig.3.2 integrates IoT and blockchain technologies to create a parking space counter with online viewing capability.

IoT devices Fig.3.1 are made up of HC-SR04 ultrasound sensors that detect the approaching objects(vehicles) and MG995 10kg-cm metal gear servo motor that are used to control the motion of the entry/exit gates. A Wi-Fi communication module is attached with each IoT device that enables communication and access server APIs. The IoT devices are also equipped with P10 LED matrix display boards (interfaced via DMD connector) in order to present the current capacity of the parking lot.

Each IoT device can be equipped with a 40W solar panels and battery management systems in order to work standalone and also to reduce the energy consumption.

IoT devices installed at entry and exit of the parking lot detect available spaces by maintaining appropriate wallet balance securely stored on a blockchain network, ensuring transparency and immutability.

Users can access the available parking spaces online through a mobile app in real-time. Blockchain's decentralized nature ensures data integrity, while IoT enhances efficiency and accuracy in monitoring parking spaces, providing a seamless and transparent parking experience. It is to be noted that this research uses a blockchain which is actually meant for the sole purpose as a cryptocurrency in the use of developing a IoT application's solution.

4. Implementation. The IoT devices have to work inclined with the XNO blockchain to handle the parking lot spaces as shown in Fig.4.1. Initially the XNO entry wallet has to be funded with a balance that would be equal to the total number of parking spaces. For example if total parking spaces are equal to 25 the XNO entry wallet balance should be equal to 0.000025 and 25 is displayed on LED board at parking entry. In the beginning the XNO exit wallet balance is 0.

When IoT device detects car at entry gate then first the XNO entry wallet balance is checked, if balance is available then 1 unit i.e 0.000001 is transferred from XNO entry wallet to XNO exit wallet and the IoT device

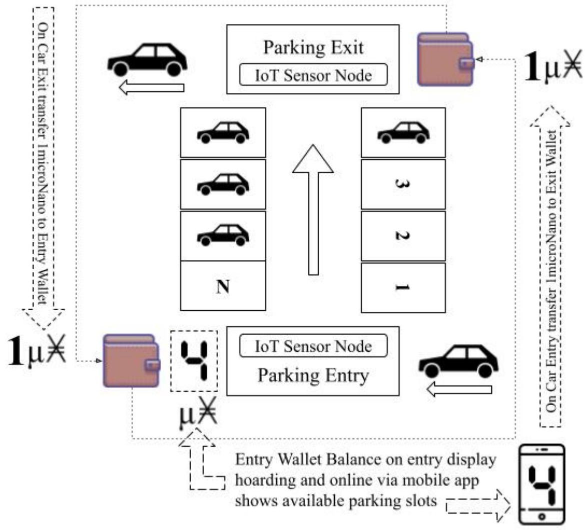

Fig. 3.2: A simplified representation of the proposed system architecture depicting various elements of the IoT-Blockchain parking space counter solution.

opens the entry gate and LED display board is updated.

Similarly when IoT device detects car at exit gate then then 1 unit i.e 0.000001 is transferred from XNO exit wallet to XNO entry wallet and the IoT device opens the exit gate.

The mobile app works in parallel and always displays the conversion of latest balance of the XNO entry wallet which represents the available number of parking slots.

In order to bring out the proposed architecture into implementation the following steps are to be undergone:-

1. ***Creating wallet, accounts and managing associated private key***: In order to work with NANO's cryptocurrency XNO we made use of NAULT [43] (as shown in Fig.4.2) which is a secure open source wallet for NANO based on NANOVAULT [44].
2. ***Setting up wallet api in each IoT node***: NANO's Node and Protocol Documentation [45] was used for this purpose along with the service from SomeNano [46] which is a free-to-use Public Nano Node.
3. ***Preparing initial wallet balance based on the assets related to the problem domain***: NANO faucets [47] allow us to claim small amounts of XNO for free. These faucets are to experience how easy it is to send and receive XNO across the world instantly on a decentralized network. A temporary NANO wallet address was used to receive XNO from the faucets. The amount of microNano equal to the total parking spaces was transferred from this temporary wallet to the parking entry wallet address.
4. ***Deciding conditions for invocation of asset transfer***: As depicted in system architecture in Fig.3.2 when the entry IoT sensor node detects a car entering the parking lot then, 1microXNO is transferred from the entry wallet address to the exit wallet address. The vice-versa is performed when a car leaves the parking lot.
5. ***Unit conversion of wallet balance to depict available parking spaces on display hoarding at entry and online via mobile app***: Account balance of the wallet assigned to the parking entry is enquired through an API call "https://node.somenano.com/proxy?action=account_balance&account=nano_xxx" which returns a JSON data as follows:-


```
{
"balance":"25000000000000000000000000",
```

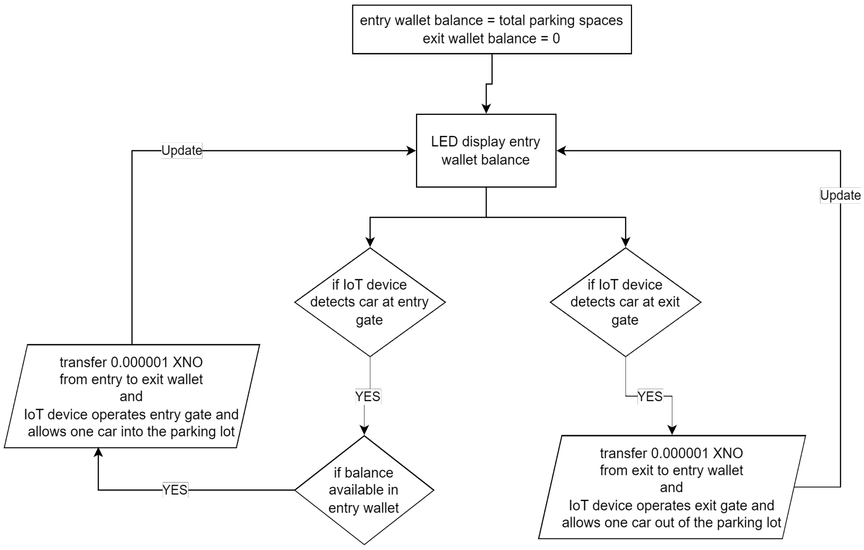

Fig. 4.1: Control flow of the proposed methodology representing the integration of IoT devices with the XNO blockchain to handle the parking space counter LED display


```
"pending":"1000000000000000000000000",
"receivable":"1000000000000000000000000",
"requestsLimit":"5000",
"requestsRemaining":"4999",
"requestLimitReset":"Sat Jul 22 2023
06:17:34 GMT+0200 (Central European Summer Time)"
}
```


Unit conversions [45] [48] are programmed to show parking spaces on display hoarding and online via mobile app. The mobile app was developed as shown in Fig.4.3 using a cloud app building service [49] and related methods [50].

5. Results and Discussions. A software [51] was used to simulate the IoT sensor nodes binded with a parking scenario in order to perform tests and observe results. The cryptocurrency being transferred during entry and exit of cars at the parking lot simulation were observed using a block explorer [52], also wallet balance including unit conversions on app were observed. All these results are shown as three scenarios in Fig.5.1, individual block information during one transfer in Fig.5.2 and multiple cryptocurrency transactions in Fig.5.3.

There are many block-chain technologies that support smart contracts through which parking space system can be managed. But, based on the approach used in this work only fee-less block-chain technologies can be used. A minor investigation portrays the attributes of such shortlisted block-chain technologies as shown in Tab.5.1. EOS is an advancing technology that has a maximum theoretical capability of 8,000 transactions per second and a minimum of 0.0001 EOS is required for a transaction. IOTA on the other hand requires 1 token per IoT device. XNO has many forks and one popular among them is Banano(BAN) and at least 0.01 of BAN token is required for transactions.

The capacity of parking lots differ from each other. If various fee-less block-chain technologies(BCT) are compared using the proposed methodology (considering the minimum tokens required in respective BCT) as shown in Tab.5.2 then XNO proves to be a viable solution. In this scenario only 1 set of IoT devices are

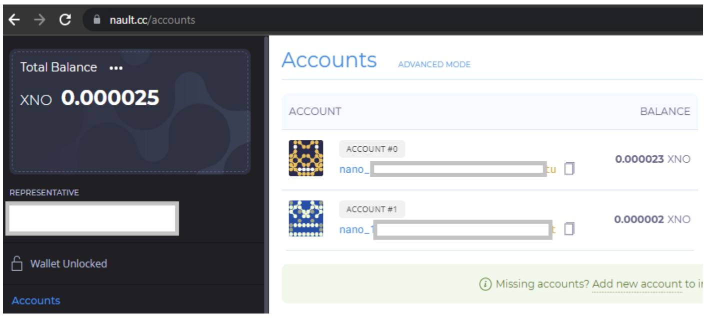

Fig. 4.2: An online wallet containing two XNO accounts: address of account#0 binded to parking entry and address of account#1 binded to the parking exit (source: nault.cc)

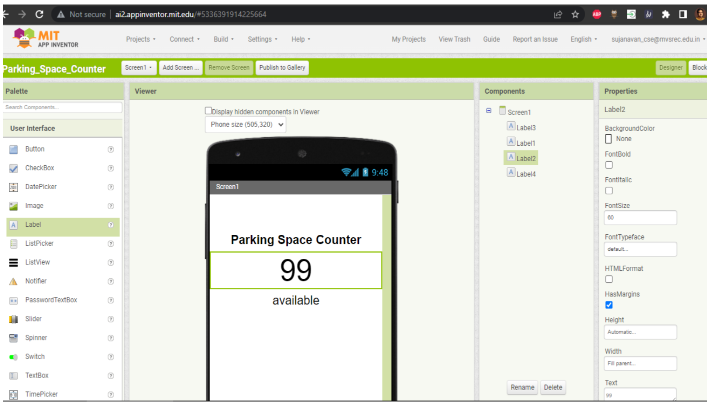

Fig. 4.3: Development scenario of the parking space counter app using MIT App Inventor (source: appinventor.mit.edu)

considered i.e. 1 IoT device at the entry gate of the parking lot and 1 IoT device at the exit gate of the parking lot. Note that XNO and its forks supports upto 30 decimal places and hence the cost change is very negligible when one parking lot contains huge number of parking spaces also.

An organization which tends to develop parking solutions based on this methodology will have to handle multiple number of parking lots. This is where XNO proves to be a viable solution as some of the other fee-less blockchain technologies tend to increase in price drastically as seen in Tab.5.3.

It was observed through this research that a cryptocurrency which is meant for money transfer can also be used to provide solutions in IoT. This solution was only possible because the block-lattice technology developed by Nano(XNO) made asset transfer fee-less and instant. Multiple parking entry and exit points can be extended with the same program without changes because the block-lattice is protected by double-spending acting as a process synchronization feature.

6. Conclusion. This research represents a significant advancement in parking management and efficiency by leveraging the Internet of Things (IoT) technology and incorporating the block-lattice mechanism, this system provides a reliable and real-time solution for monitoring and managing parking spaces in various urban and commercial settings.

The implementation of this system offers several key benefits. First and foremost, it enhances the overall

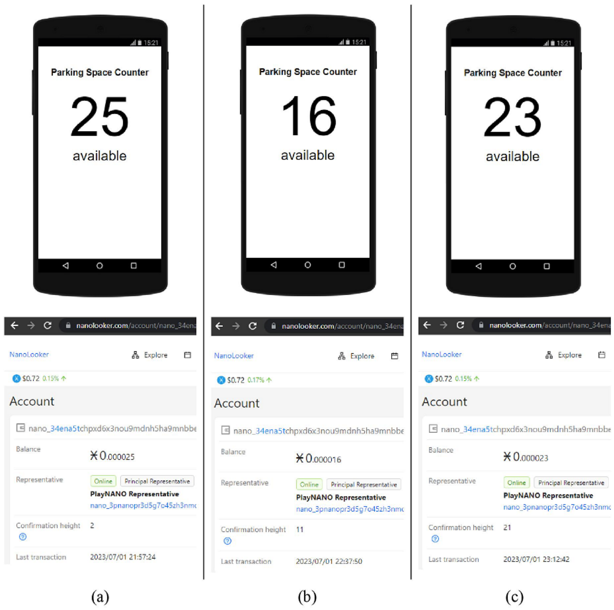

Fig. 5.1: Representation of parking space counter in accordance with wallet balance for various scenarios: (a)Initial Wallet balance is set equal to the total number of parking slots. 0.000025 Nano is represented on the phone display after conversion as 25microNano, (b)After some cars enter the parking lot the wallet balance decreases in proportion and updated on counter display at parking entry & app, (c)After some cars exit the parking lot the wallet balance increases in proportion. All updates are shown on display hoarding at parking entry & online using mobile app(photos above in first row).

Table 5.1: Attributes of various fee-less block-chain technologies that were considered for comparative study.

Block-chain	**Max. TPS**	**Min. Token required (cost in USD)**
EOS	8,000	0.0001 EOS ($0.00006354)
IOTA	1,000	1 IOTA ($0.158295)
XNO	1,800	0.000001 XNO ($0.000000682)
BAN	XNO fork	0.01 BAN ($0.00004091)

Table 5.2: Tokens required of the related block-chain and cost in USD for implementing the proposed methodology using various block-chain technologies for varying parking lot capacities ahving only 2 IoT devices; 1 at entry gate and 1 at exit gate.

BCT	**for 25 spaces**	**for 50 spaces**	**for 100 spaces**
EOS	0.0025 ($0.0015939)	0.005 ($0.0031879)	0.01 ($0.0063758)
IOTA	1.000025 ($0.17)	1.00005 ($0.17)	1.0001 ($0.17)
XNO	0.000001($0.0000007)	0.000001($0.0000007)	0.000001($0.0000007)
BAN	0.01 ($0.00004)	0.01 ($0.00004)	0.01 ($0.00004)

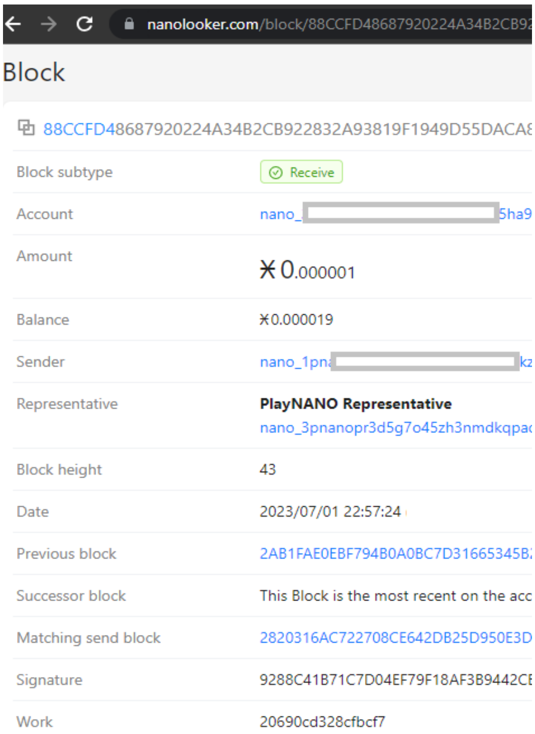

Fig. 5.2: Transaction block information which can be used to issue parking tickets as it contains timestamp and unique block hash (source: nanolooker.com)

Fig. 5.3: Transaction history of entry wallet where "Send" denotes a car entering the parking lot and "Receive" denotes a car exiting the parking slot (source: nanolooker.com)

parking experience for drivers by reducing the time spent searching for available spaces. This, in turn, leads to reduced traffic congestion and improved air quality in urban areas. Additionally, the system optimizes parking space utilization, maximizing revenue generation for parking lot operators and ensuring fair distribution of spaces among users.

Moreover, the integration of blockchain-based block-lattice technology ensures a secure and tamper-resistant

Table 5.3: Capital investments for various block-chain technologies if opted by organizations using the proposed methodology with multiple number of parking lots (with 100 spaces and 1 set of IoT devices) in different geographical locations.

BCT	for 10 lots	for 100 lots	for 1000 lots
EOS	0.1 ($0.063758)	1 ($0.63758)	10 ($6.3758)
IOTA	10 ($1.7)	100 ($17)	1000 ($170)
XNO	0.00001($0.000007)	0.0001($0.00007)	0.001($0.0007)
BAN	0.1 ($0.0004)	1 ($0.004)	10 ($0.04)

data recording process in order to issue parking tickets. The decentralized nature of the block-lattice mechanism eliminates the risk of a single point of failure and enhances the system's resilience against potential cyber threats.

In conclusion, this innovative parking space counter system represents a step forward in transforming a cryptocurrency to solve traditional parking management by using an efficient, and user-friendly process. As IoT and blockchain technologies continue to evolve, we can expect even more simpler and integrated solutions to revolutionize urban mobility and shape smart cities of the future.

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