

Creating a New IoT Ecosystem

Infrastructure with Multi-Tiered

Blockchains

Whitepaper V3.4 nesten.io



nesten

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Abstract



The telecommunications industry is entering a new era of 5G, and with it, ubiquitous connectivity and the massive business potential associated with the Internet of Things(IoT). It is also facing unprecedented financial and technical challenges to providing the widespread, low-cost coverage needed for the constant machine-to-machine communications required for the IoT. These obstacles have deep roots in the legacy infrastructure that still dominates telecommunications in most countries: Incumbent carriers continue to operate networks, because the high cost of establishing and maintaining these networks is a prohibitive barrier to entry. Unfortunately, these centralized network providers and their cellular voice/data-centric systems—are poorly equipped to harness the power of IoT and deploy densely populated networks in a cost-effective manner. This barrier to entry has stifled growth and innovation—but now, the inception and refinement of blockchain technologies have finally opened the door to a solution.

Nesten represents a technology and business paradigm shift: We envision a communications infrastructure supported by the collective efforts of network participants, who are primarily the owners of Nesten Wireless Nodes and devices. In support of this individually operated ecosystem, the Nesten system uses multi-tiered blockchains to operate its network and run its financial incentive system. The deployment process can be individually managed, not unlike setting up a WiFi router at home. The blockchains integrated in the system will ensure the network's security as well as the integrity of financial processes. They will also accurately and securely maintain the operational history and the authentication records. Data requests will be handled reliably through the multi-tiered blockchains without human intervention. In short, the essence of the Nesten ecosystem is to use connection and coverage incentives to motivate individual owners to utilize their existing Internet connections to set up the Wireless Nodes needed for the IoT.

We also believe the IoT industry requires an entirely new financial system to lend itself to a wide range of use cases. As the IoT data are generated and travel through the network, the system needs a highly efficient financial infrastructure that can handle micro-level transactions without overhead fees. For this reason, we are deploying New IoT Token (NIT), a new cryptocurrency to serve as a medium for transactions within the network. It is set to launch in the summer of 2019.

After more than 3 years of development, we started shipping in the beginning of 2019 and have deployed 200 Wireless Nodes in five major metropolitan areas in the U.S. and overseas. By the end of 2019, thousands of Wireless Nodes are expected to be in full operation across North and South America and Asia. The Wireless Node is a high-performance computing platform combined with multiple wireless communications standards and high-precision GPS. It is designed to handle complex communications and blockchain protocols, as well as advanced machine learning to identify critical events. Using the hierarchical architecture of delegated Proof of Stake, the blockchain protocol is optimized for speed and scalability to accommodate the massive expected data growth.

Our platform will harness these technologies to produce not only the most secure and efficient IoT infrastructure available, but also high returns for Nesten equipment owners and NIT investors. The Wireless Nodes will be strategically incentivized to motivate high availability and wider coverage. Device owners will also have opportunities to monetize their device investment by sending the wireless link quality measurements and geolocation data to the system. With the wireless quality measurements, the system will be able to map out and present a graphical view of wireless coverage with estimated signal quality at different locations. In addition, Nesten's inclusion of Proof of Work in its consensus mechanism will not only provide further support to the incentive ecosystem, but also ensure that the blockchains are secured with extensive computing requirements.

Nesten is developing and delivering IoT infrastructure with advanced IoT-optimized blockchains. With hundreds of the Wireless Nodes already running across the country and overseas and more expected within 2019, Nesten has outpaced the competition and is leading the transformation of the telecommunications industry.

1. Introduction

Today's wireless telecommunications infrastructure primarily focuses on voice and content delivery for users on centralized carrier networks. Typical use cases may include voice calls, audio/video streaming, and Internet/social browsing. As we enter a new era of machine-generated communications, the system needs to offer an entirely new level of security and scalability to accommodate the sheer number of devices and mission-critical use cases.

The market research firm IoT Analytics estimated that in 2018, there were 7 billion IoT devices around the world, excluding smartphones, tablets, laptops, and fixed line phones [1]. These Internet of Things (IoT) devices may extend their uses into critical infrastructure, such as utilities systems, with implications for national security in areas like electricity and energy distribution. The number of active IoT devices is expected to grow to 10 billion by 2020 and 22 billion by 2025 [1]. In terms of market size, the global IoT market valuation was \$151 billion in 2018, and it is forecasted to grow to \$1.5 trillion by 2025 [1]. This growth potential is supported by the revenue and income growth rates of companies working in spaces across the spectrum of IoT software, cloud, and services.

Given the large and growing number of connected devices, the IoT architecture requires a highly secure, distributed network where the data can be neither manipulated nor attacked by malicious attempts on centralized data centers. With blockchain technology, data are cryptographically encrypted and stored in a digital ledger distributed over a large number of nodes. If a data modification is needed, it requires a consensus from the participating nodes, so an attempt on a single node will be denied.

Nesten proposes a versatile, extensible, multi-tiered blockchain architecture to operate on a wide range of devices at a massive scale. The multi-tier architecture ensures that each blockchain operates efficiently and optimally to accommodate the unique characteristics of the network elements (devices, Wireless Nodes, and users). On the financial side, the Nesten incentive system not only allows a highly cost-effective pricing structure, but also creates the possibility of achieving wide area coverage via collective networks of individually owned Wireless Nodes.

2. Blockchained IoT

2.1 Security Challenges for Centralized Cloud Networks

Most of the current IoT solutions are based on centralized cloud networks. In a centralized network architecture, the network/data management and control are concentrated in data centers managed by large existing companies. We believe there are significant issues with the centralized approach that present obstacles if the massive IoT revolution is to take place.

In a centralized network infrastructure, security and data breaches are the most significant issues for mission-critical IoT applications. Because adversaries can focus on a centralized data center, the networks are exposed and vulnerable to malicious attacks. This is not speculation: In April 2019, the world's biggest social network suffered the latest of many reputation-damaging breaches when it was revealed that records for more than 540 million users had been publicly exposed on Amazon cloud servers. Another significant security breach occurred in 2018, when the private information of 383 million Starwood Hotels and Resorts guests was exposed, including 9.1 million payment card numbers and 23 million passport numbers.



2.2 Blockchained IoT

Blockchain is a network consisting of append-only distributed ledgers, which are “blocks” linked with one another. Once a network is set up with blockchain, it operates autonomously without central authorities. Modification of encrypted data stored in the ledgers requires a consensus among nodes to “approve” the change.

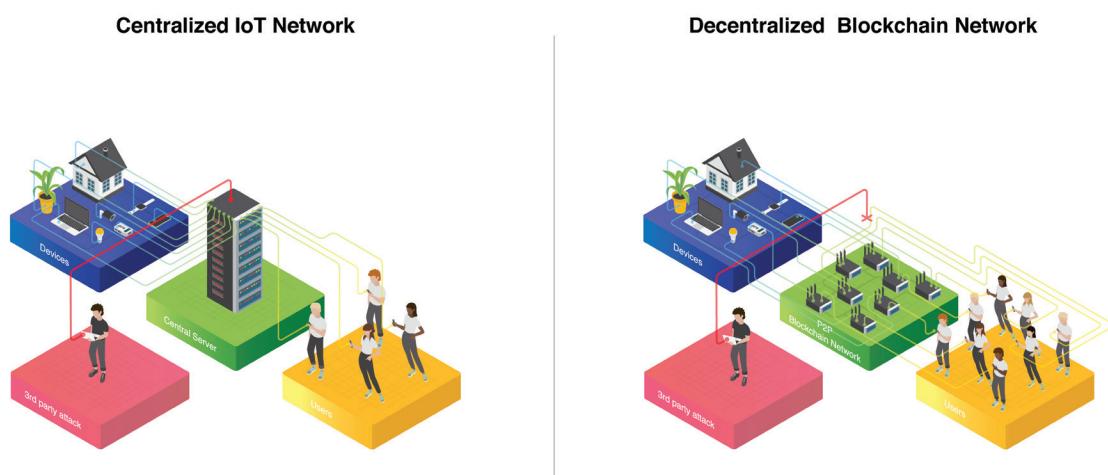


Figure 1. Single-point failure issue for centralized IoT network. With a blockchain IoT network, any malicious attacks would be isolated and recoverable from distributed ledgers

Figure 1 illustrates the vulnerability of the centralized network, in which a malicious attack on the central server can paralyze the entire network. In the decentralized blockchain IoT network, the attack would be isolated and recoverable, as the ledgers are duplicated on other nodes.

| Challenges | Centralized IoT Cloud | IoT with Blockchain |
|-------------------------|---|---|
| Data Security |  Vulnerable due to single point failure |  Cryptographically encrypted |
| Data Privacy |  Potential for misuse |  Encrypted and operated with blockchain |
| Network Deployment Cost |  Significant due to installation logistics |  Moderate as the network is set up by motivated individuals |

Table 1. Advantages of blockchain IoT and disadvantages of centralized IoT cloud

3. Nesten: Multi-Tiered Blockchain IoT

The Nesten ecosystem consists of three system elements: Wireless Nodes, users, and devices.



User

- Registered owners and/or data consumers
- Use a blockchain to register and authenticate other users to prevent any malicious network intrusions

Wireless Node

- Key element to maintain the network infrastructure
- Create/operate the blockchains
- Perform data encryption and wireless protocols
- Need to operate 24/7, requiring high reliability
- Block generation can occur once a day

Device

- Generate location/sensor data
- Devices must be registered and data must be authenticated
- Blockchain can handle data streams from a large number of devices
- Interfaces with third-party storage networks for raw data archiving

Figure 2. Multi-tiered blockchains for device, wireless node, and user

Our approach is to provide a separate blockchain for each of the network elements to maximize the system operation's robustness and reliability. The system must continue to operate at all times even when certain Wireless Nodes experience outages due to power and/or Internet connection failures. As described in Section 4, each of the elements operates with different set of operating characteristics based on those elements' unique functions. For instance, the device blockchain needs to respond to real-time events and therefore requires frequent updates, while the user management blockchain may require updates much less frequently.

4. System Overview

The Nesten network is built on decentralized Wireless Nodes with support for multiple wireless protocols: LoRa, WiFi, and Bluetooth Low Energy (BLE). These Wireless Nodes are connected through the IP network infrastructure, and their operation is supported with multiple layers of blockchains that address the different needs of the system elements.

4.1 Nesten Network

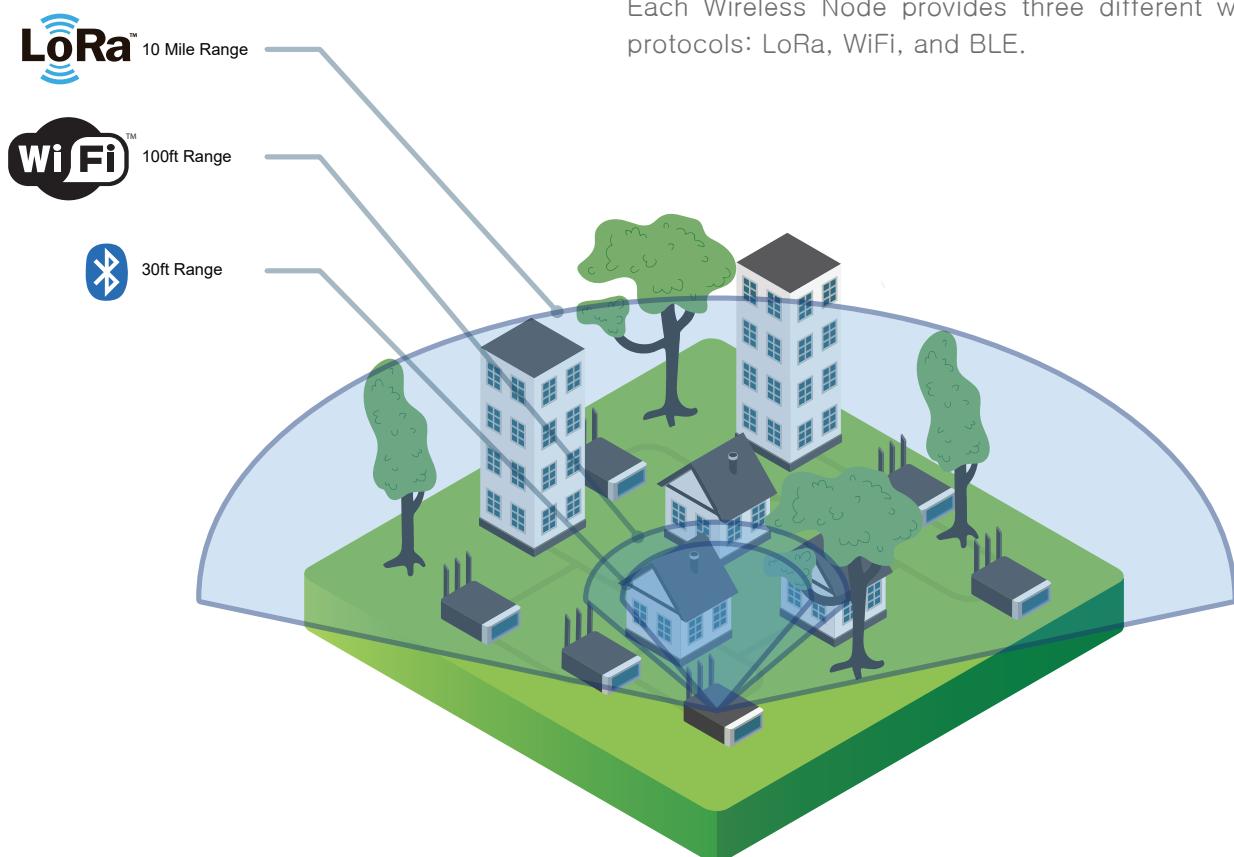


Figure 3. Overview of Nesten system infrastructure

4.2 Nesten Wireless Node

4.2.1 System Architecture

The Nesten Wireless Node is a high-performance computing platform combined with multiple wireless protocols to encompass different user scenarios and coverage ranges. LoRa is a wide-area radio protocol, and its extended coverage capability and low power consumption are particularly well suited for the IoT network. LoRa is our primary focus in the initial network deployment to foster the adoption of IoT ecosystem. WiFi will provide a blockchain network of WiFi hotspots through which users can easily access the Internet without a cumbersome login process. Inclusion of BLE will further extend the Nesten Wireless Node's applicability, as nearly 4 billion Bluetooth® devices are forecasted to ship in 2018 alone.

The Wireless Node is designed to support the wireless protocols as well as the extensive blockchain processing. Figure 4 shows the Wireless Node architecture with key hardware elements in the lower box and software components in the upper. In the hardware layer, the Nesten Wireless Node utilizes an i.MX8 from NXP Semiconductors; the i.MX8 is a quad-core ARM processor, one of the most advanced low-power processors. This technology will enable the Wireless Node to perform the wireless protocols as well as blockchain processing. The software runs on a 64-bit Linux operating system with a complete network server, the inclusion of which allows data parsing, processing, and routing to support the blockchain operations.

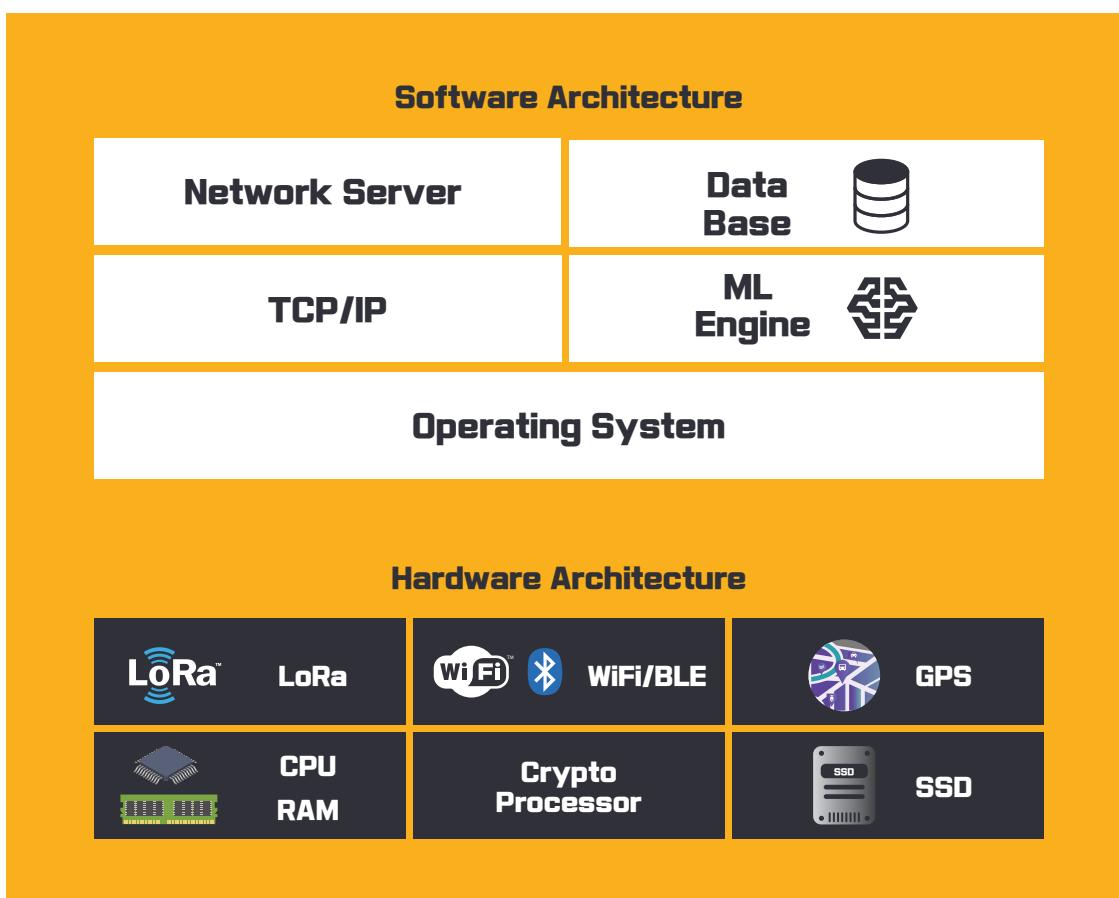


Figure 4. System overview of Nesten wireless node

4.2.2 System Specifications

| Subsystem | Category | Item | Specification |
|------------------|----------------------|---------------------|-------------------------|
| Processors | CPU | CPU Name | NXP i.MX 8M Quad |
| | | CPU Type | 4x Cortex-A53 |
| | | CPU Cores | 4 |
| | | CPU Clock | 2 GHz |
| LoRa Radio | Memory | RAM | 4GB LPDDR4 |
| | | eMMC | 128GB |
| | Graphic | 3D Graphic Accel | GCNanoUltra |
| | | Video Encode/Decode | 1080p60, H.265, and VP9 |
| WiFi & Bluetooth | Networking | Ethernet | 10/100/1G |
| | Frequency Bands | Europe / India | 863 MHz - 870 MHz |
| | | USA / Korea | 902 MHz - 928 MHz |
| | | Australia / Japan | 470 MHz - 510 MHz |
| | Channel Proccessiong | | 8 LoRa channels |
| | Sensitivity | | -139 dBm |
| | Tx Output | | 26 dBm |
| | WiFi | WiFi | 802.11ac |
| | | Bluetooth | BT4.1 |

Table 2. Nesten wireless node specifications

4.3 Machine Learning for IoT Data

The basic premise of the IoT is to deploy a vast array of sensors and trackers to fully automate environmental and industrial processes. We believe that in a few years, these wireless sensors will become pervasive in all major industries, as well as consumers' everyday lives. They will produce tremendous amounts of data to analyze and store; these data have the potential to improve productivity for the manufacturing process, better health for individuals, and lifestyles with more leisure time as everyday chores become automated.

The main challenge associated with this ever-increasing data generation is the ability to analyze and detect any significant events in real time. Nesten's approach to this challenge is rooted in built-in machine learning (ML) capabilities. The ML will be implemented with a multi-layer neural network, as shown in Figure 5.

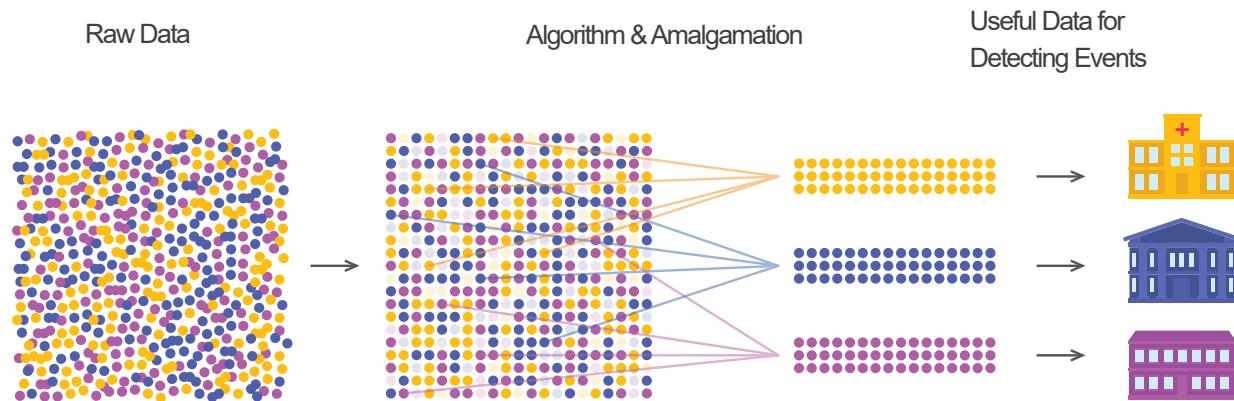
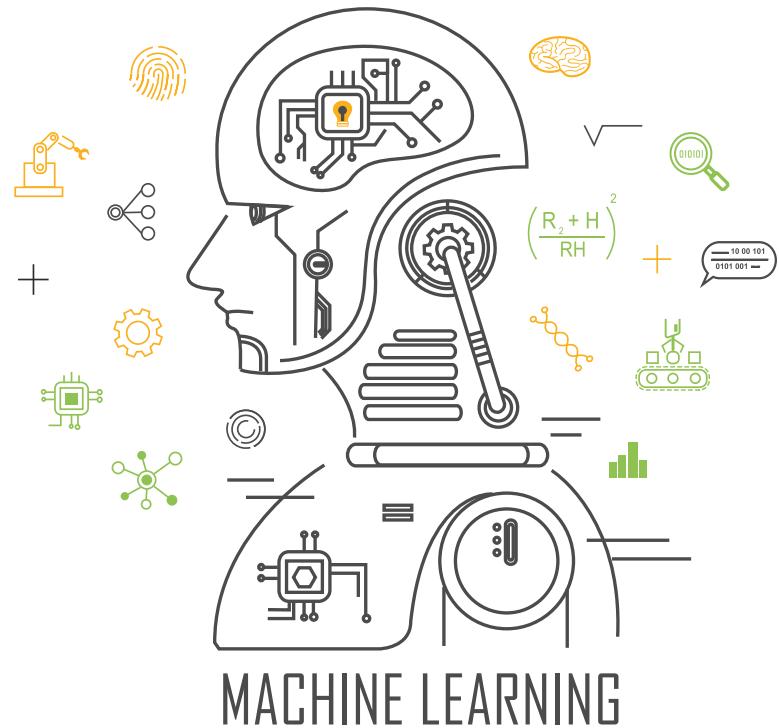


Figure 5. Neural network-based machine learning to autonomously detect safety critical events

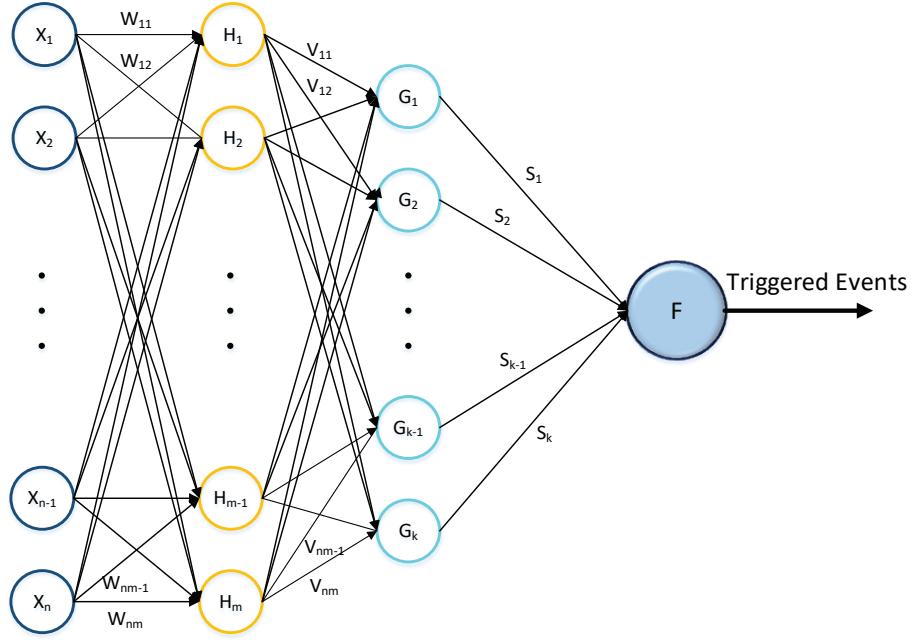


Figure 6. Deep learning neural network for IoT data extraction and event triggering

Time Series of Sensor Data: [... $X_1 X_2 \dots X_{n-1} X_n \dots]$

The time series may continuously run as long as the sensor stays on to generates data. As the amount of data will continue to grow, our strategy is to focus on data processing and key event extraction with the deep learning neural network. The raw data will be transferred over to distributed storage networks.

As shown in Figure 6, the neural network may consist of multiple layers to enhance its capability to address complex data patterns. The key point is that the number of weights can be preconfigured and confined. As such, they can be included in the blocks along with event details.

The weights are the key to the data analysis, as they are responsible for generating alerts for users. Once the data are filtered through processing, the sensor data's time series would be transferred over to the third-party blockchain storage network, where it will then be stored for pre-defined periods. The neural network will continuously monitor the data stream and generate events based on pre-conditioned scenarios.

Weights of Inner Layer: [$W_1 \dots W_m ; \dots ; W_{n1} \dots W_{nm}$]

Weights of Hidden Layer: [$V_1 \dots V_m ; \dots ; V_{n1} \dots V_{nm}$]

Weights of Outer Layer: [$S_1 \dots S_k$]

4.4 Nesten Network with Blockchain

4.4.1 Network Architecture

The Nesten network can be logically partitioned into the control and data planes along with the third-party storage network

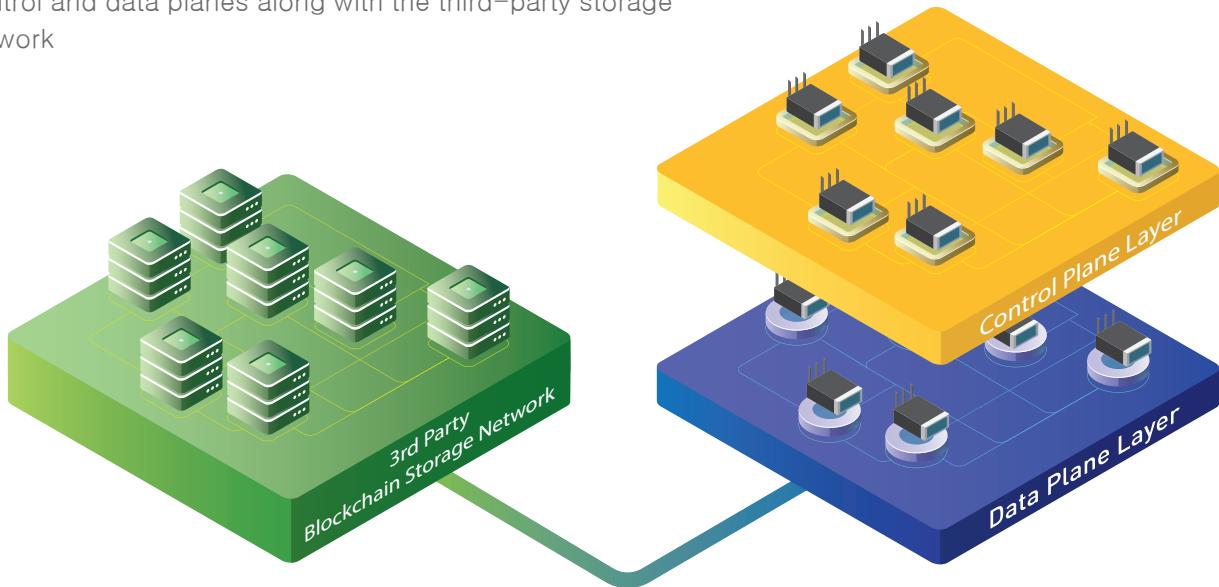


Figure 7. Nesten network architecture with third-party storage network and logical partitioning into control and data planes

4.4.2 Control and Data Planes Blockchain

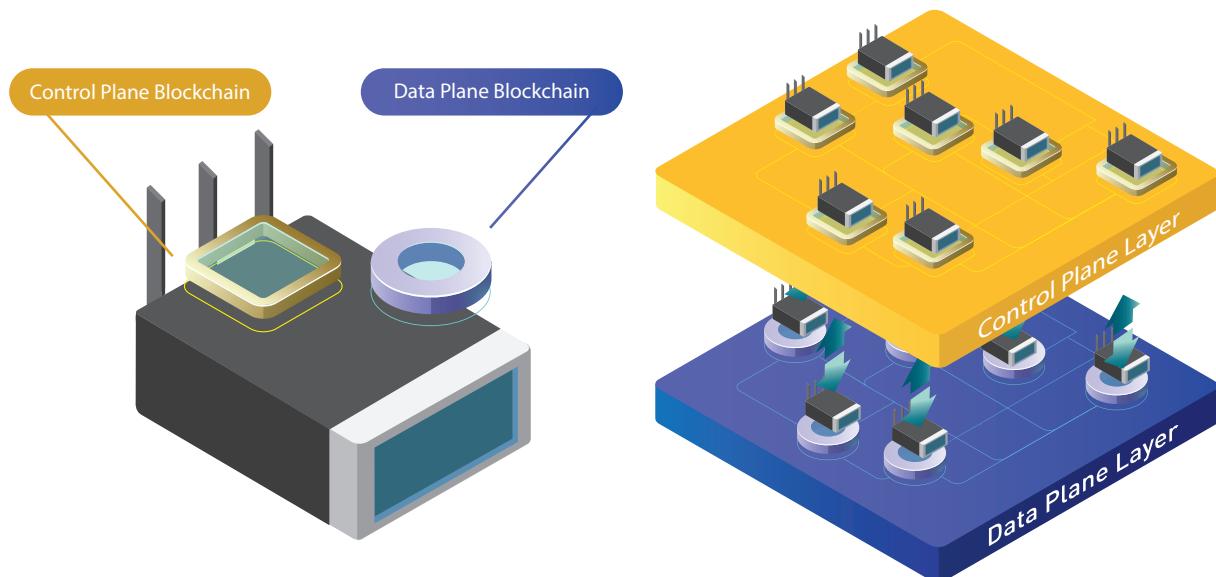


Figure 8. Nesten's blockchain architecture includes a logical partitioning of control and data planes

- **Control Plane**

The control plane employs three separate blockchains to manage users, devices, and Wireless Nodes. Each of these elements includes different operating characteristics, such as block contents, block synchronization intervals, and security mechanisms.

- **Data Plane**

Also known as the forwarding plane, the data plane is responsible for sending the data traffic to the selected network destination according to the control plane protocol.

4.5 Multi-Tiered Blockchain for Control and Management

4.5.1 User Management

The user management blockchain is responsible for access control and key management. The access control includes user authentication as well as data requests.

Once the user enters a data request, the blockchain authenticates the validity of the user. After the user is authenticated, the request is forwarded to the data plane, which then proceeds to data retrieval from the third-party blockchain storage network.

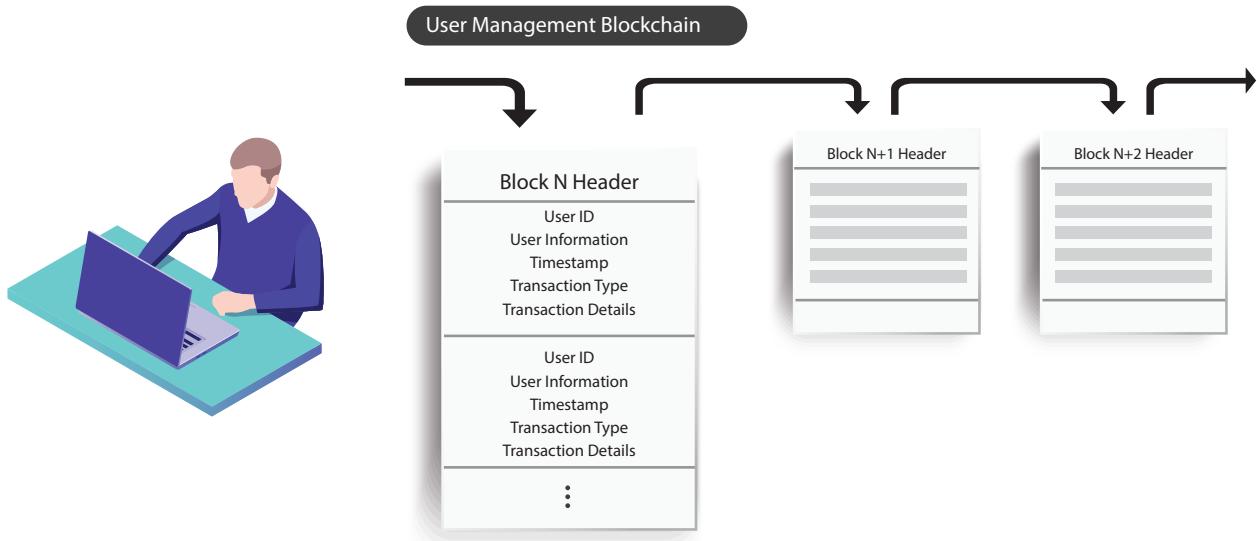


Figure 9. Blockchain generation for user authentication and management

4.5.2 Wireless Node Blockchain

The Wireless Node blockchain plays a significant role in maintaining the Nesten decentralized infrastructure, as the system relies on the Wireless Node network to function properly. As such, the blocks are structured to accurately log its operational activities, such that the Wireless Node owners are incentivized to maintain the Wireless Nodes' availability and maximize their usefulness. Performance metrics will be implemented to measure the uptime as well as the quality of the Internet connection.

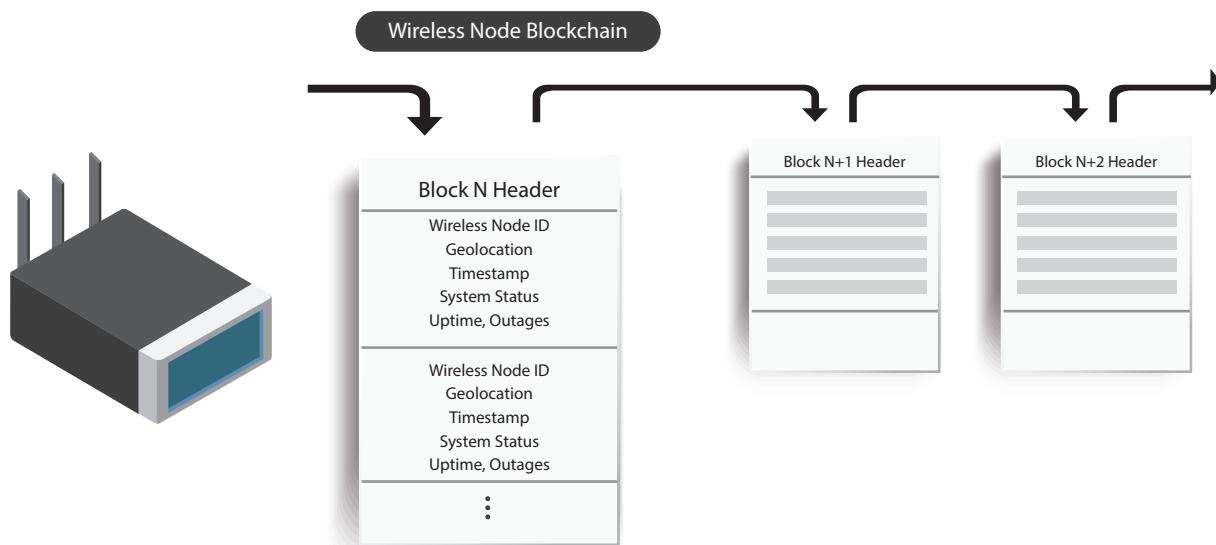


Figure 10. Blockchain to operate the decentralized Nesten wireless node

4.5.3 End Device Blockchain

We expect that there will be a large array of end devices running on the Nesten network. These devices may include both Nesten-designed devices and partnership products. Due to the nature and potential use cases of IoT applications, the blockchain should be scalable to accommodate expected growth in data needs. Our approach is to focus on device authentication and protection against malicious attack. At the same time, the Wireless Node will be able to extract and recognize any key events and notable changes in sensor data streams.

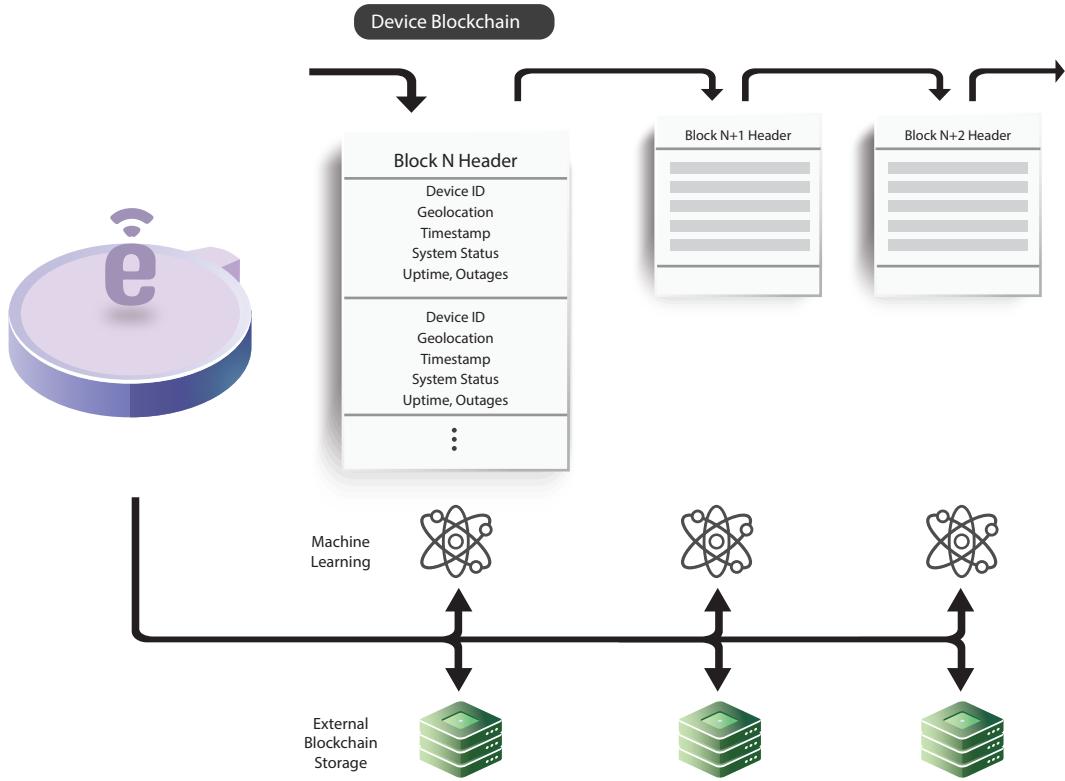


Figure 11. Device data management handled with the data plane blockchain

As shown in Figure 11, machine learning based on a multi-layer neural network will be used to extract triggered events. This alleviates the required storage space in the Wireless Node and still retains the key information of the tags. For storing the raw device data, our strategy is to leverage other blockchain-based storage networks. The distributed blockchain storage networks are expected to be more secure than centralized cloud storage operators as the data are encrypted, split, and transmitted to a large array of nodes. It is also expected to be more cost-effective than a centralized approach.

4.6 Blockchain Consensus

The Nesten blockchain consensus is primarily based on the concept of Delegated Proof of Stake (DPoS). However, the “voting” process will utilize three building elements: Proof of Stake (PoS), Proof of Work (PoW), and the Performance Metrics (PM) of the Wireless Node. We name this blockchain platform Hybrid-DPoS (H-DPoS).

H-DPoS leverages benefits of each of the building elements and combines them to operate the multi-tiered Nesten network. PoW is primarily responsible for generation of valid blocks and ensures security with extensive hashing computations. DPoS will decide whether to accept the PoW generated blocks into the network and well suited for IoT data management due to its speed and scalability. The Wireless Node’s PM will help to improve the quality of network operation by motivating Wireless Node owners to continuously monitor their Wireless Nodes’s operation and take any corrective action if necessary.

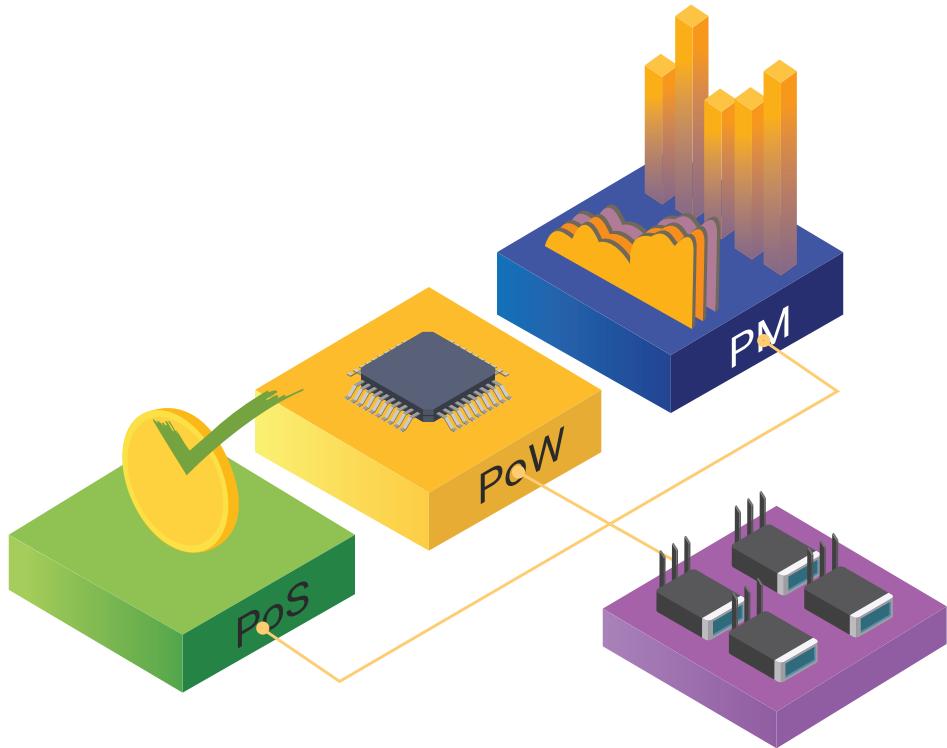


Figure 12. In H-DPoS, delegates are “elected” based on Proof of Stake, mining capability, and wireless node performance metrics

4.6.1 Proof of Stake (PoS)

DPoS paves the way for a large-scale IoT network. The DPoS consensus is achieved through “elected delegates,” as opposed to the entire set of the Wireless Nodes. The “elected delegates” are a subset of Wireless Nodes selected by NIT coin holders. These elected delegates will be responsible for validating transactions and creating blocks. In addition, as the network grows larger, DPoS lends itself to a hierarchical structure, as described in Section 4.6.5.

4.6.2 Proof of Work (PoW)

PoW ensures that the blockchain is maintained with strong cryptographic hash computations, and thereby minimizes the risk of invalid transactions. Nesten Wireless Nodes include a high-performance cryptographic processor that is capable of performing most crypto algorithms.

4.6.3 Wireless Node Metrics

The Wireless Nodes must continue operating at all times with high-quality Internet connections. Wireless Node outages can cause unreliable system performance, resulting in service interruptions and gaps. By incentivizing the Wireless Node owners to maintain maximum availability with quality Internet connections, we can maintain high network reliability. The Wireless Node metrics will track the amount of data traffic as well as the data’s usefulness to end users.

4.6.4 Block Voting Process

The block generation will be achieved in a two-step process. In the first step, the PoW will generate valid blocks, which will be then passed onto the DPoS delegates. In the second step, the DPoS delegates will decide whether to accept the latest block into the network. The acceptance will require 60% of the votes from the DPoS delegates.

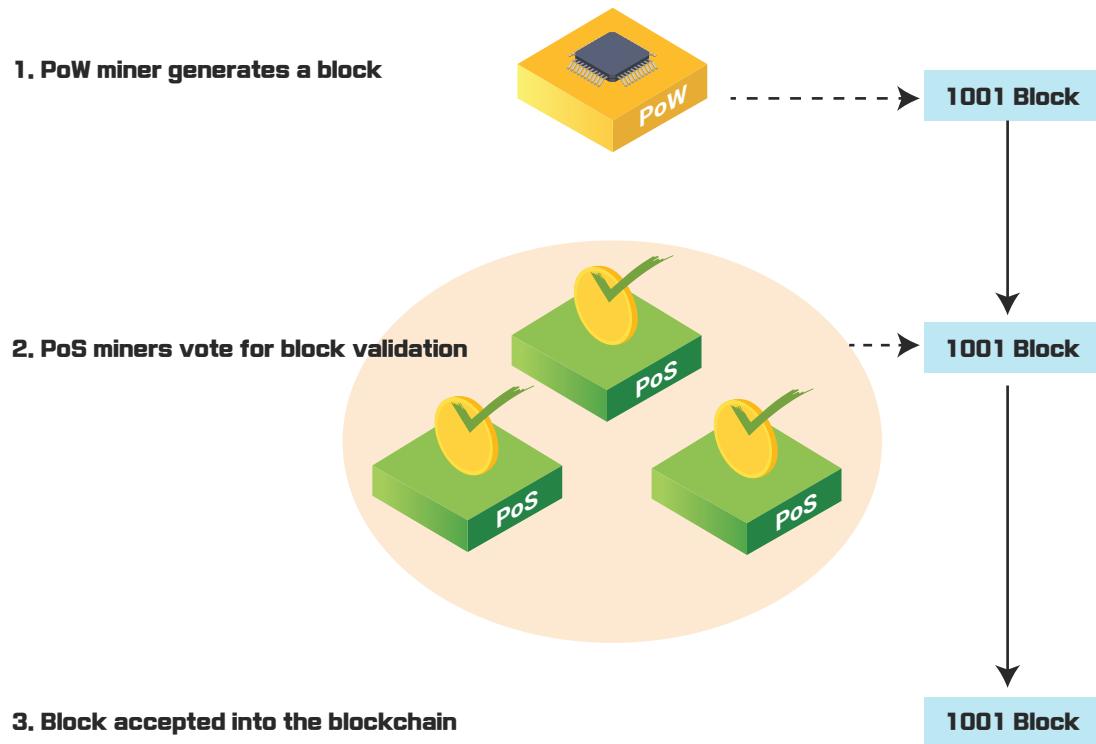


Figure 13. Block voting process

4.6.5 Hierarchical H-DPoS

Given the expected high number of delegates amongst the growing community, we propose a hierarchical delegate structure as shown in Figure 14 to further improve speed and scalability. The super-delegates are of higher importance and ensure the network is protected from any malicious users and devices, whereas the delegates are designed to promote efficient data processing. The super-delegates are also central to the Nesten's governance. For any changes to the network protocol, mining, and consensus algorithm, more than 60% of the votes from super-delegates are required.

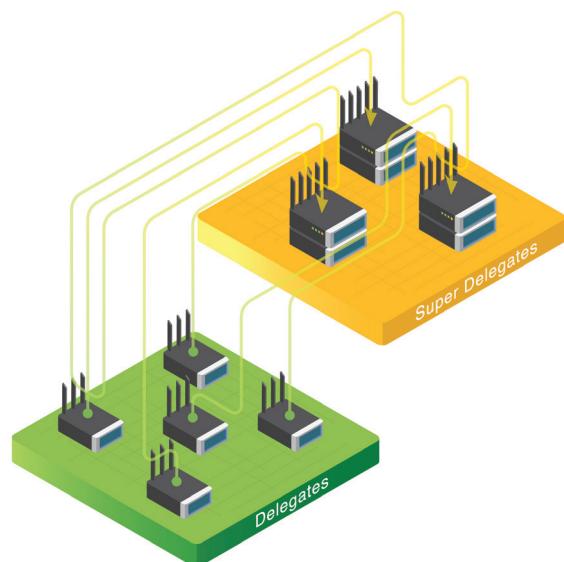


Figure 14. Hierarchical delegate structure

4.7 Device Authentication and Registration Process

The control plane blockchain will handle new device registration as well as authentication, as illustrated in Figure 15. The device registration information will pass through the data plane and be processed in the control plane.

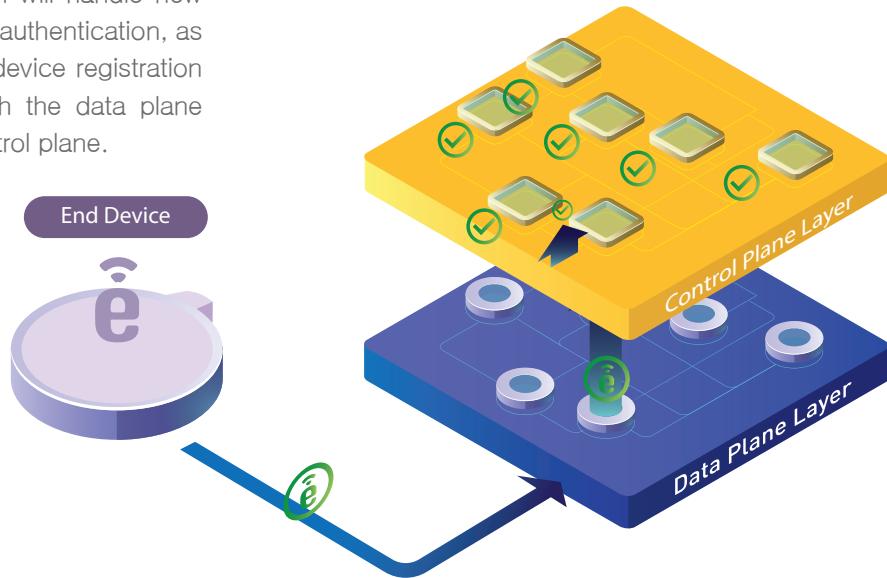


Figure 15. User data request and retrieval

4.8 Data Requests

For data access, a user enters a data request on application software, e.g., an app on a smartphone. A potential use case might involve a user who wants to monitor the status of his or her bicycle parked outside a building during the day. In the network, the request is submitted to the control plane, which verifies that the request came from a valid user and generates a command to retrieve the data from the third-party storage network.

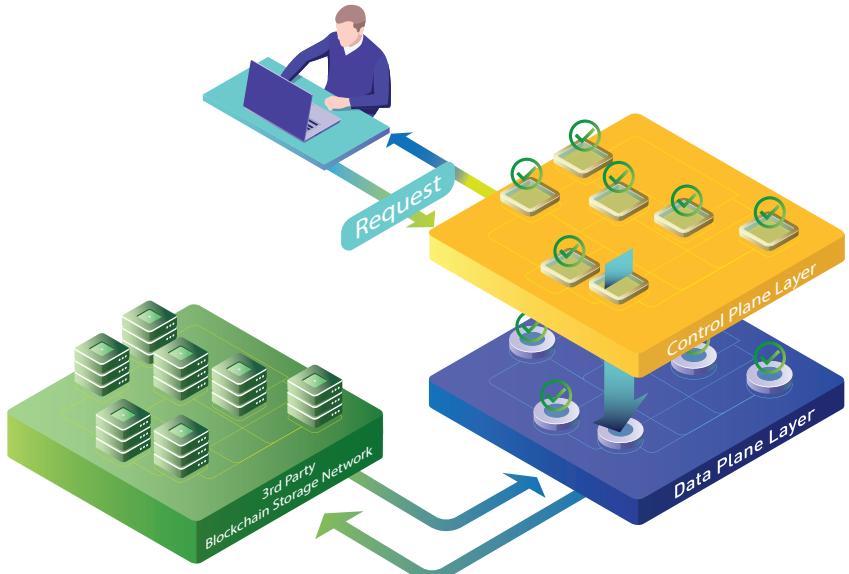


Figure 16. User data request and retrieval

5. The Nesten Ecosystem and Token Economics



5.1 Overview

The Nesten ecosystem is designed to support all of the network participants in the IoT-centric system. The three core participants are:



Data users

The consumers of the data collected in the repositories. The data users may include consumers as well as enterprise customers. The users can comprise of consumers and enterprise customers.



Wireless Node hosts

The pillars of the network. The hosts are rewarded for operating the Wireless Nodes and generating the blocks.

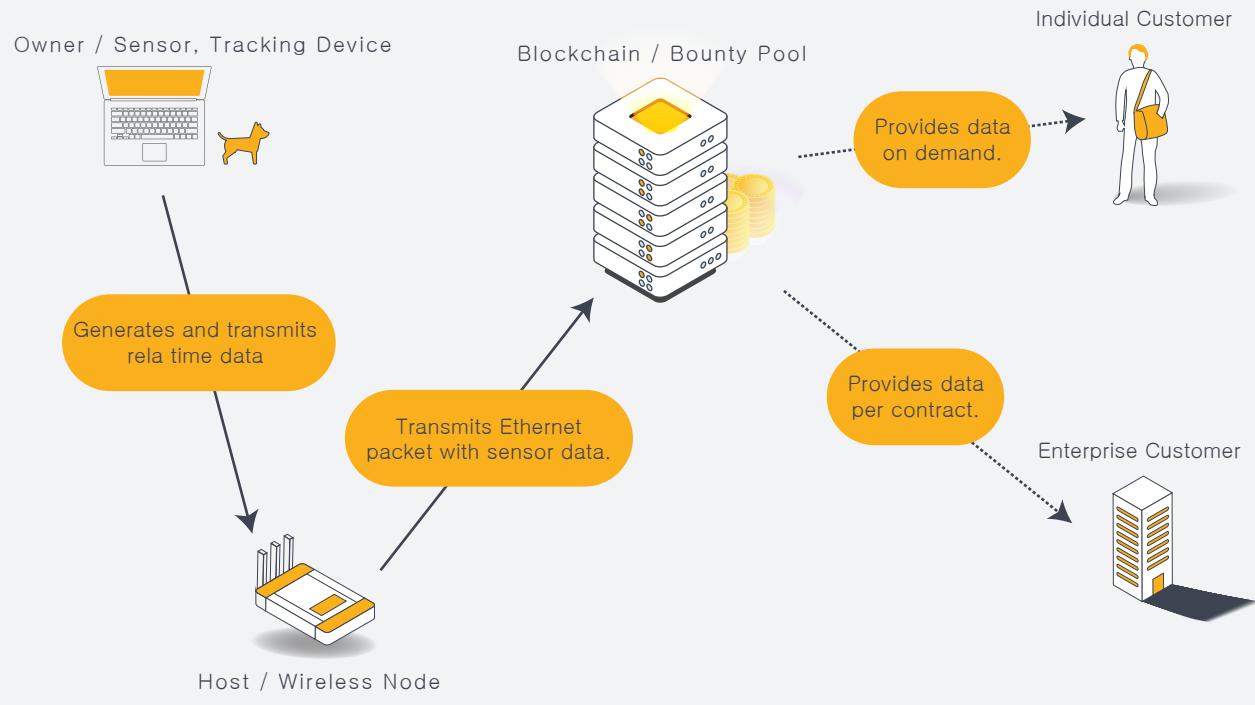


Device owners

Purchase and operate Nesten devices. They can be rewarded for providing of resourceful data. When they purchase devices for their own valuables, they also become the data users.

As shown in Figure 17, the Nesten network maintains an “escrow” pool to enable an efficient financial ecosystem, minimizing minuscule transactions that are expected to occur in IoT systems.

Network Operation in Data Perspective



Network Operation in Financial Perspective

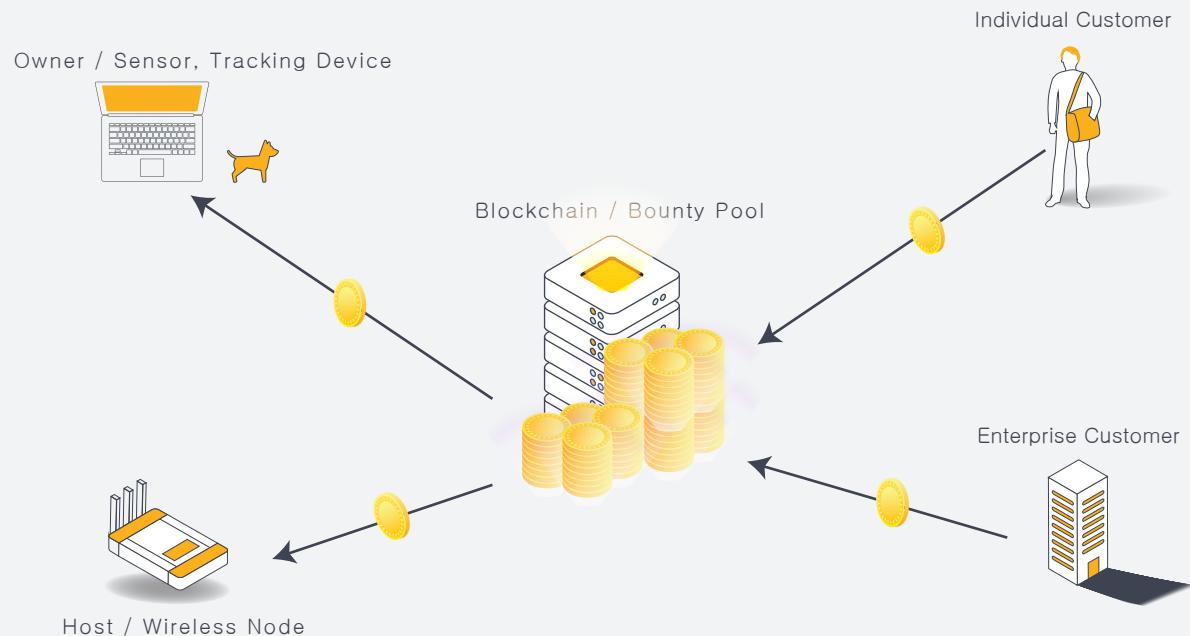


Figure 17. Nesten ecosystem

5.2 New IoT Token (NIT)

The New IoT Token (NIT) is the essential currency to support the Nesten ecosystem. The NIT can be used for data access, and the G1/G1s owners will be financially compensated via NIT.

In terms of technical implementation, the NIT will be created based on Ethereum's ERC-20 cryptocurrency. The NIT will then be circulated within Nesten's own private network, operating semi-independently of the public Ethereum blockchain.

This private approach alleviates the extensive processing tasks required to operate on the public Ethereum blockchain. In the public Ethereum blockchain, every node needs to process every transaction occurring in the network. To minimize the computational and storage overheads, the Nesten blockchains will originate from their own genesis block, and the block processing will be performed within its own network.

5.2.1 Handling of Microtransactions

In most cases, IoT data transmissions will incur only a tiny fraction of one NIT coin. As such, an actual commercial transaction will take place only when a user accumulates a certain number of data transmissions and/or requests above a preset threshold. This thresholding mechanism is essential to minimize overhead associated with coin transactions. A simple example may be a location tracking use case in which a GPS tag may be sending its location every minute. This will amount to 720 data transfers per day. It will be far more efficient to execute a single financial transaction over a sufficient period as opposed to each occurrence.

As mentioned in 5.1, the Nesten blockchains will maintain escrow pools to reduce the number of transactions that can occur across the different domains of data users, Wireless Node hosts, and device owners. In essence, each of the network participants will only need to interact with the escrow pools. This will also help to reduce minuscule peer-to-peer transactions.

5.3 Token Economics

The Nesten ecosystem's members can be grouped into demand- and supply-side actors.

5.3.1 Demand Side

The demand side includes data users, who can be grouped into two types: consumers and enterprise customers. Consumers may include people who would like to use Nesten devices to track personal valuables. Enterprise customers may desire data access for business applications. Potential business applications include delivery tracking

5.3.2 Supply Side

The supply side includes the G1 hosts as well as the device owners. These participants are either service or data providers. The G1 Wireless Nodes generate and validate blocks as well as operate the network. The device owners are data providers.

Table 3. Incentives for G1 hosts and device owners

| G1 Hosts | | | Device Owners |
|---|------------------|--|--------------------------------------|
| DPoS | PoW | PM | Data Provider |
| Block validation and network protocol consensus | Block generation | Provides backhaul connection and wireless coverage | Provides sensor and geolocation data |

5.4 Token Allocation and Distribution

The total NIT allocation is 1 billion coins, of which 250 million will be made available through private sales and the IEO.

| Item | Description | Percentage |
|------------------------|---|------------|
| Token Sales | Current IEO and future token sales | 25% |
| Foundation | Nesten foundation (open software developers) | 10% |
| Research & Development | Technical development team for wireless nodes and devices | 20% |
| Ecosystem | Financial incentives to support the ecosystem | 10% |
| Advisors | Nesten technical and business advisors | 5% |
| Partners | Marketing and management partner | 20% |
| Reserve | | 10% |
| Total | | 100% |

Table 4. NIT token distribution

5.5 Use of Funds

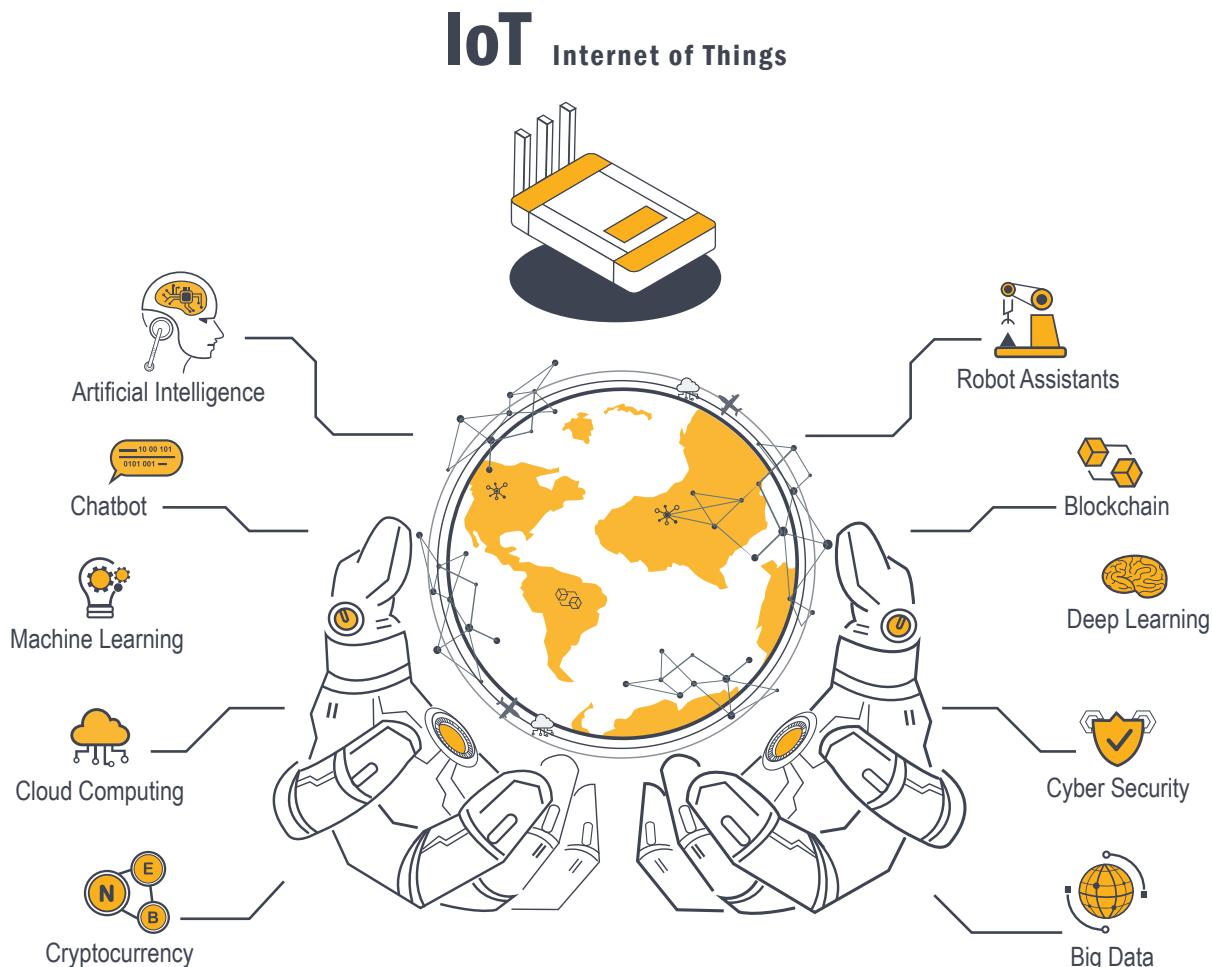
The funds raised from our IEO will accelerate our growth through wireless coverage expansion, blockchain implementation, and technology marketing.

| Item | Description | Percentage |
|------------------------|---|------------|
| Research & Development | Continued technology development and blockchain implementation | 30% |
| Marketing Expenses | Marketing efforts and campaigns to expand coverage and device ownership | 30% |
| SG & A Expenses | Selling, general and administrative expenses | 30% |
| Reserve | | 10% |
| Total | | 100% |

Table 5. Breakdown of IEO fund uses

5.6 Well Positioned for IoT Growth

The term IoT comprises of many technologies, ranging from short range communications, e.g. Bluetooth, to long-range radios, including LoRa and cellular communications. The potential applications also span multiple industries: consumers, agriculture, industrial, smart cities, and connected buildings. Even in each application there may not be a one-size-fits-all. Practical and realizable solutions may require several wireless technologies working together seamlessly. As such, the blockchain implementation as well as the financial ecosystem need to be flexible and extensible.



The Nesten network and ecosystem shares this basic principle to be able to adapt to technical and financial challenges of building a heterogeneous system. The multi-tiered blockchains can be extended to accommodate additional network participant layers. The G1 Wireless Node includes multiple wireless protocols of WiFi, Bluetooth, GPS, and LoRa. Given the team's background, additional communications technologies can be built into the system to provide a comprehensive solution to customers' needs.

6. Roadmap



6.1 Progress

As of May 2019, a total of 200 G1 Wireless Nodes have been delivered to early backers of the project. Close to 120 G1s are in operation in Texas, most notably in Dallas and Houston. 12 G1s are running in California, and 8 are in the New York, New Jersey, and Washington DC areas. We also have 4 G1s in Korea and China.



Figure 19. G1 Genesis Model

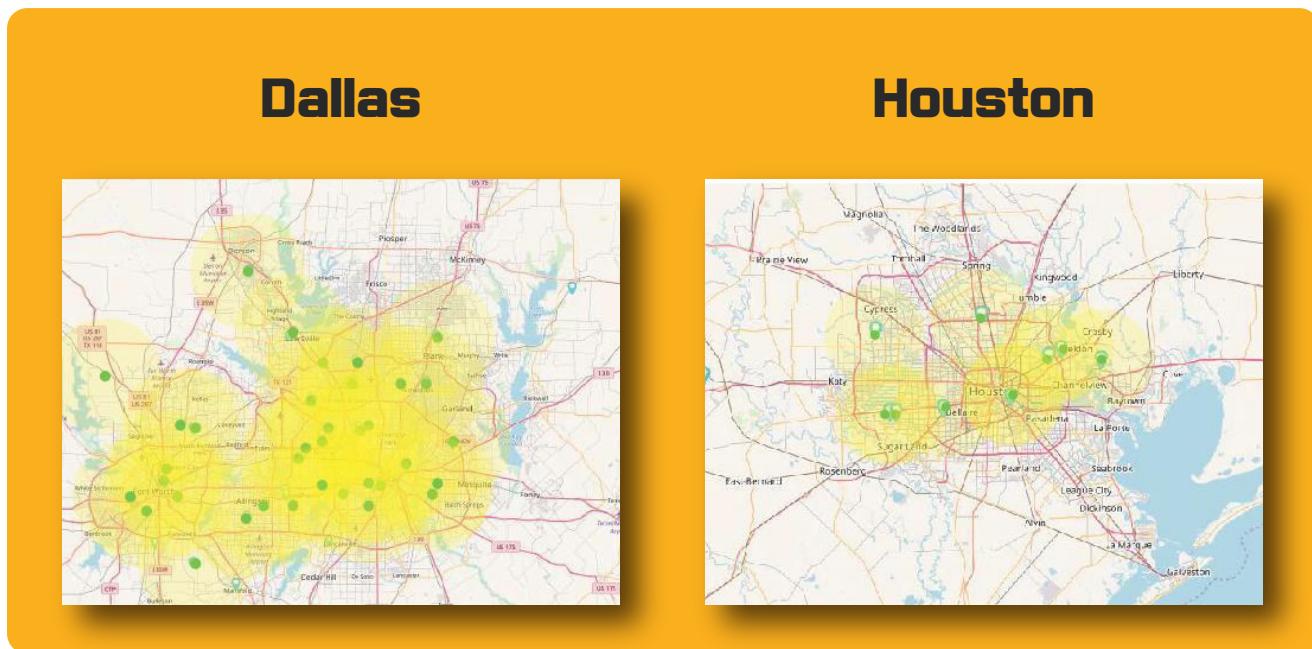


Figure 20. Dallas (left) and Houston (right) coverage

7. Team

Andrew Baek, PhD

- As founder of Troicom and Citius Systems, successfully developed and delivered unique, high-performance systems for top-tier enterprise clients in electronics and medical technology
 - 60 GHz Gigabit Ethernet wireless system
 - Ultra-wideband (UWB) wireless solution for precision indoor positioning
 - High-precision hand/finger gesture recognition based on millimeter wave radar technology
- Principal Investigator to secure SBIR funding from US Department of Defense to develop a hybrid photonic and electronic ultra-wideband low-power digitizer
- Led advanced communications system development: cellular systems, WLAN/WPAN, Software Defined Radios, and satellite communications at Lucent Bell Labs and Northrop Grumman
- NASA Graduate Student Research Program fellow
- PhD and MS in EE from University of Pennsylvania; BA in Physics from Cornell University

Hoon Paek, PhD

- Extensive experience in Artificial Intelligence (AI) systems, deep learning algorithms, web platforms, and image/video processing
- Chief system architect to develop deep learning-based AI system for industrial IoT environments for one of the largest steel companies
- Developed and delivered a software system to transform unstructured document images and achieve Optical Character Recognition and Optical Mark Recognition for top-tier financial institutions in Korea
- Founder and CTO of startup to perform video context search with social network service
- Chief systems architect to develop automotive video analytics from Advanced Driver Assistance Systems (ADAS)
- PhD, MSc, and BSc in EE from Seoul National University

Vince Pham

- Currently responsible for all PCB and RF designs
- 25 years of experience developing high frequency RF designs, ranging from sub 1GHz to millimeter waves, as well high-speed digital interconnections of 10GHz and above
- Key RF engineer for development of 100G optical transceivers and 60G wireless at Qlogic and Raytheon
- MS in EE from Cal State, Northridge, and BA in EE from University of California, Los Angeles

Sean Chen

- 30 years of RF system and IC development experience
- Managed and led high-volume communications IC development at MStar Semiconductor and Realtek
- MS and BS in EE from Tsinghua University, China

Robert Tong

- 20 years of FPGA and IC development experience at startups and Philips
- Successfully designed and delivered a complex digital module based on 5G-ready Common Public Radio Interface (CPRI)
- BS in EE from University of California, Irvine

Joe Xing

- 15 years of extensive embedded software development experience
- Led software architecture development of 4G LTE base stations at Lucent Bell Labs and BTI Wireless
- Designed and developed timing-critical embedded software for call control features in mobile switching center equipment
- ME and BS in EE from University of Science and Technology of China

IoT Software Engineer

- Built large-scale IoT systems with cloud integration
- LPWAN with IoT Platforms: IBM Bluemix, AWS IoT Cloud, ThingsBoard

8. References

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 - (vi) units in a business trust;
 - (vii) derivatives of units in a business trust; or
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