US012793087B2

(12) **United States Patent**
Hudec et al.

(10) **Patent No.: US 12,793,087 B2**
(45) **Date of Patent: *Nov. 10, 2026**

(54) **SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION**

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(72) Inventors: **Richard Hudec**, Naples, FL (US); **Davin Young**, Fort Myers, FL (US)

(73) Assignee: **SecureTap LLC**, Sheridan, WY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **19/187,298**

(22) Filed: **Apr. 23, 2025**

(65) **Prior Publication Data**

US 2025/0252453 A1 Aug. 7, 2025

Related U.S. Application Data

(63) Continuation of application No. 19/017,891, filed on Jan. 13, 2025, now Pat. No. 12,314,963.
(Continued)

(51) **Int. Cl.**
G06Q 30/018 (2023.01)
H04L 9/00 (2022.01)

(52) **U.S. Cl.**
CPC ***G06Q 30/0185*** (2013.01); ***H04L 9/50*** (2022.05)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

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(Continued)

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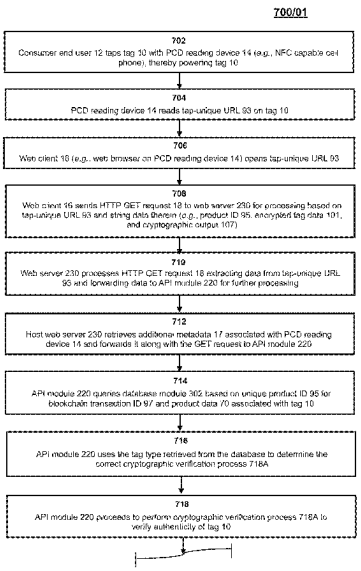
Primary Examiner — Sarah M Monfeldt
Assistant Examiner — Michael J. Monaghan
(74) *Attorney, Agent, or Firm* — Richard A. Catalina, Jr.

(57) **ABSTRACT**

A system, method and process for product authentication and verification using Near Field Communication (NFC) technology, blockchain technology (Hyperledger), and cryptography. A unique product identifier is generated for a unique individual product, incorporated into a data structure, and the data structure is recorded to a blockchain initiating an immutable record for the unique product identifier. An NFC tag is encoded with a tap-unique URL comprising the unique product identifier and a cryptographic output and affixed to the product. Each time the tag is tapped by a proximity coupling device, a web client operating on the proximity coupling device opens the URL whereupon the tag is verified using a cryptographic verification process and generating a verification result. The verification result is recorded on the blockchain ledger for the unique product identifier, thereby creating an immutable record of each tap interaction result.

18 Claims, 23 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 63/716,270, filed on Nov. 5, 2024, provisional application No. 63/680,113, filed on Aug. 7, 2024, provisional application No. 63/555,458, filed on Feb. 20, 2024.

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2023/0031817	A1*	2/2023	Mulas	G06Q 20/208
2024/0160868	A1*	5/2024	Larsson	G06K 7/10297
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2024/0412208	A1*	12/2024	Loreth	H04L 9/3247

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* cited by examiner

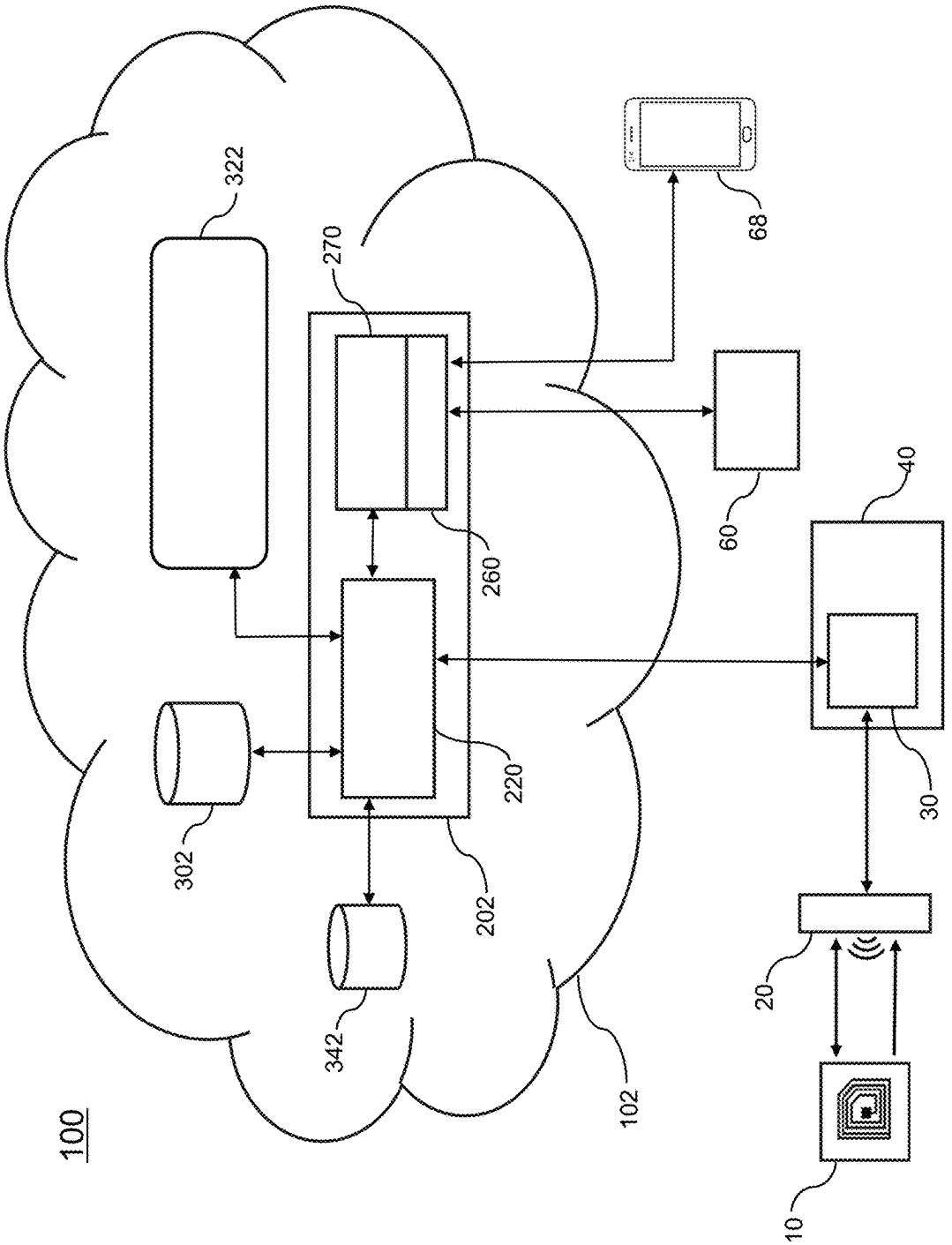


FIG. 1

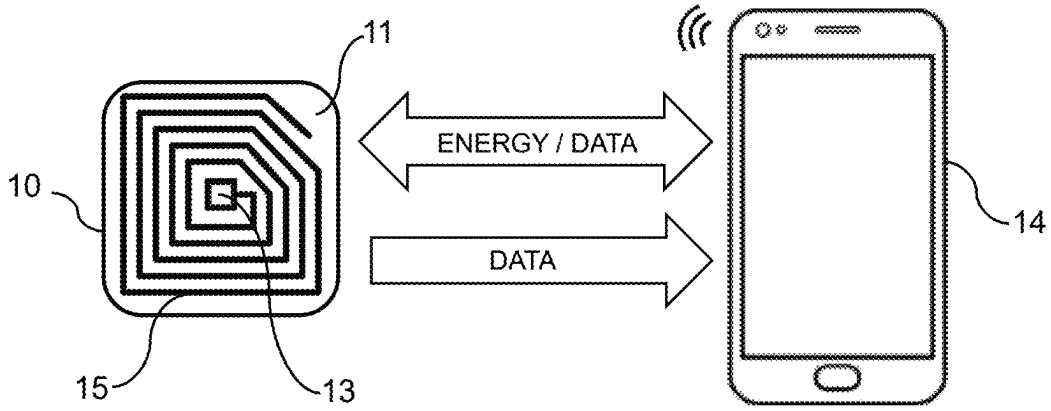


FIG. 2

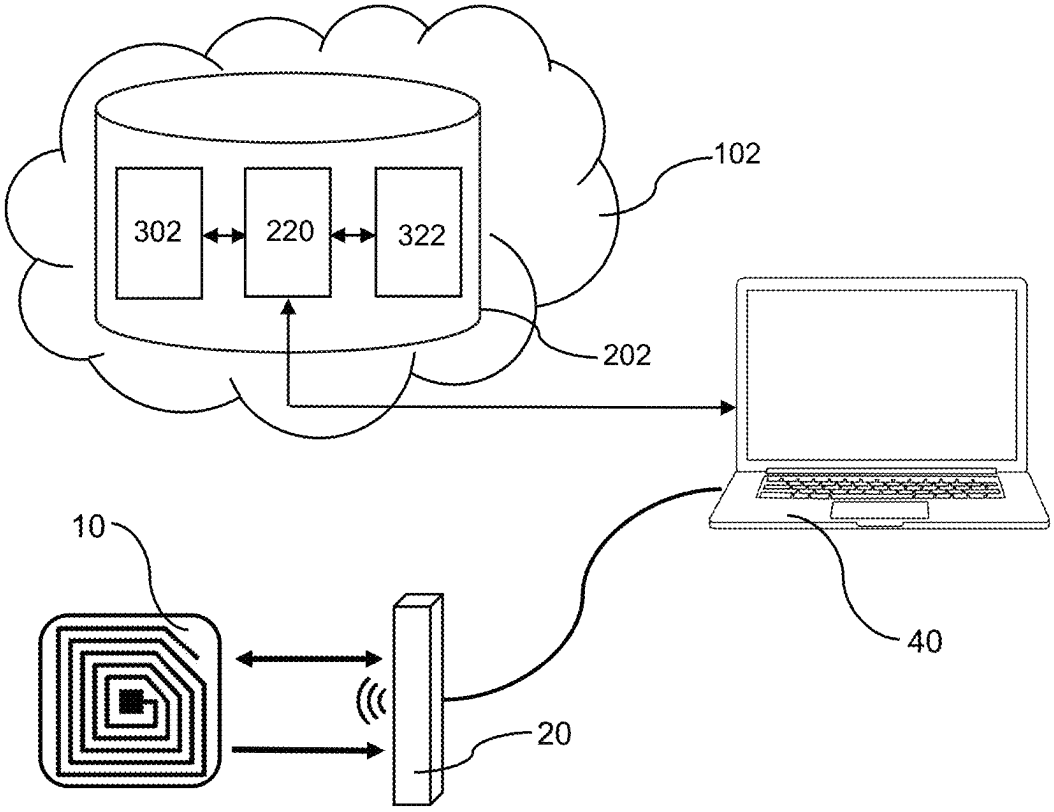


FIG. 3



FIG. 4

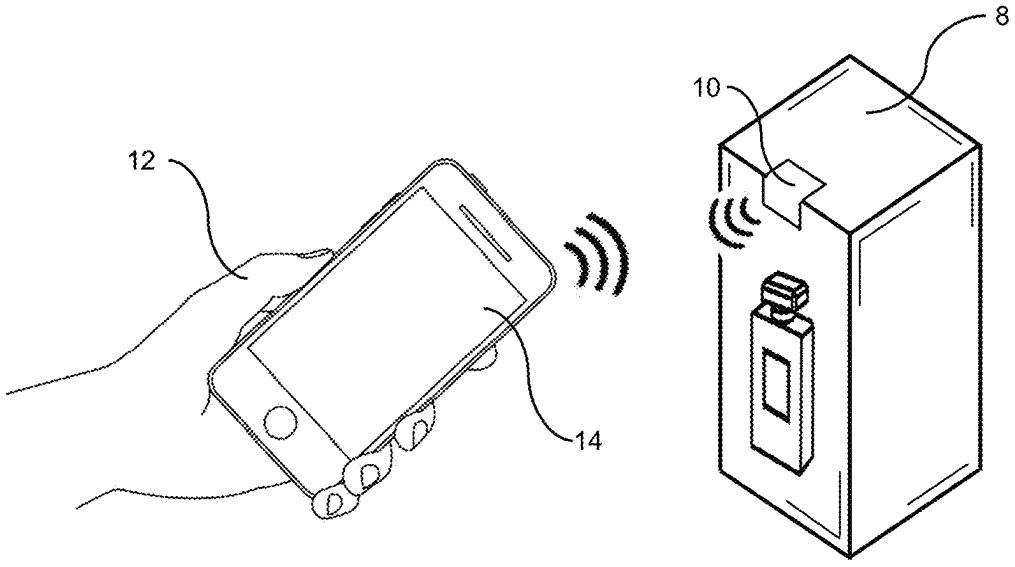


FIG. 5

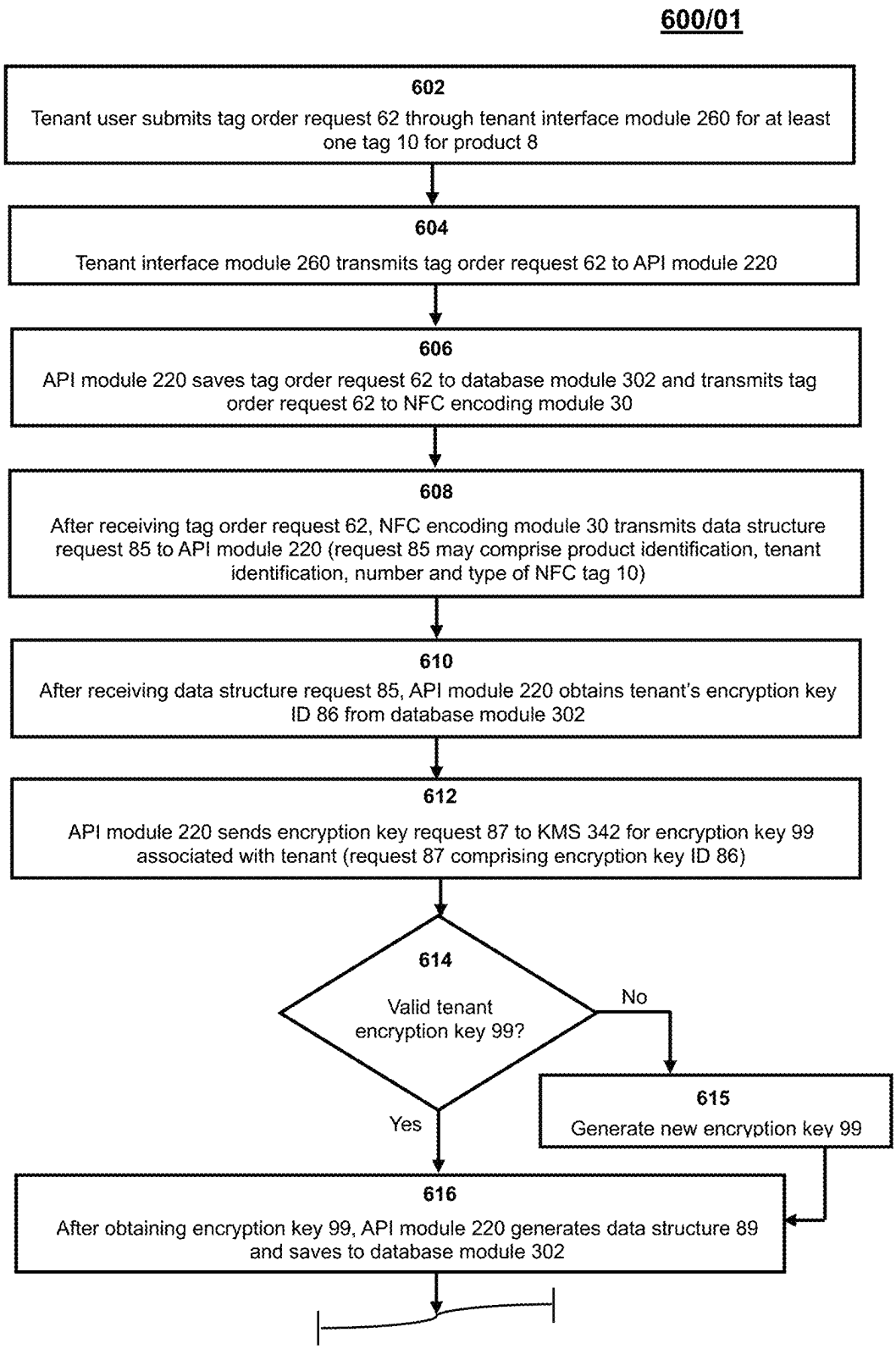

600/01
602
Tenant user submits tag order request 62 through tenant interface module 260 for at least one tag 10 for product 8
604
Tenant interface module 260 transmits tag order request 62 to API module 220
606
API module 220 saves tag order request 62 to database module 302 and transmits tag order request 62 to NFC encoding module 30
608
After receiving tag order request 62, NFC encoding module 30 transmits data structure request 85 to API module 220 (request 85 may comprise product identification, tenant identification, number and type of NFC tag 10)
610
After receiving data structure request 85, API module 220 obtains tenant's encryption key ID 86 from database module 302
612
API module 220 sends encryption key request 87 to KMS 342 for encryption key 99 associated with tenant (request 87 comprising encryption key ID 86)
614
Valid tenant encryption key 99?
No
615
Generate new encryption key 99
Yes
616
After obtaining encryption key 99, API module 220 generates data structure 89 and saves to database module 302

FIG. 6A

600/02

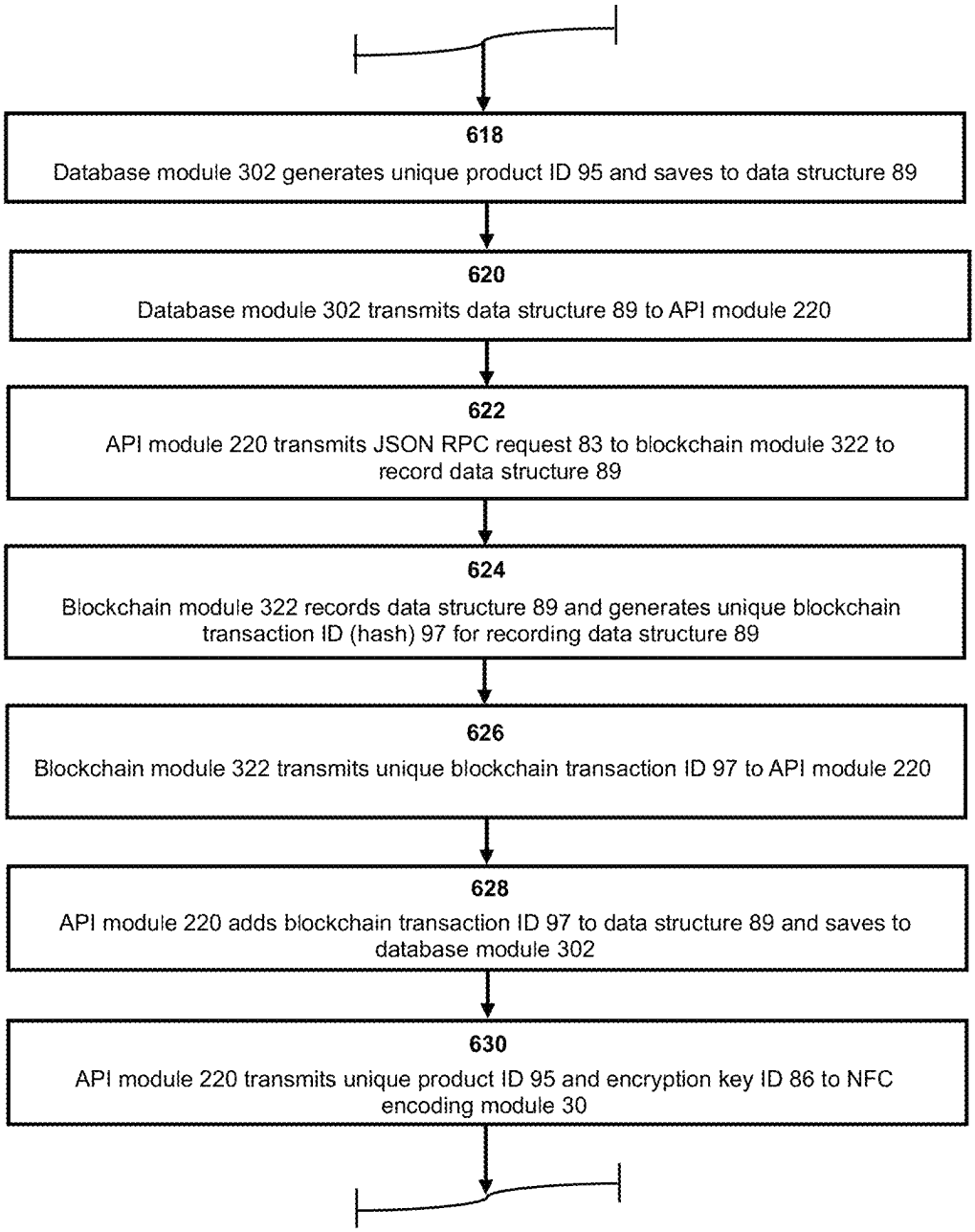

618
Database module 302 generates unique product ID 95 and saves to data structure 89
620
Database module 302 transmits data structure 89 to API module 220
622
API module 220 transmits JSON RPC request 83 to blockchain module 322 to record data structure 89
624
Blockchain module 322 records data structure 89 and generates unique blockchain transaction ID (hash) 97 for recording data structure 89
626
Blockchain module 322 transmits unique blockchain transaction ID 97 to API module 220
628
API module 220 adds blockchain transaction ID 97 to data structure 89 and saves to database module 302
630
API module 220 transmits unique product ID 95 and encryption key ID 86 to NFC encoding module 30

FIG. 6B

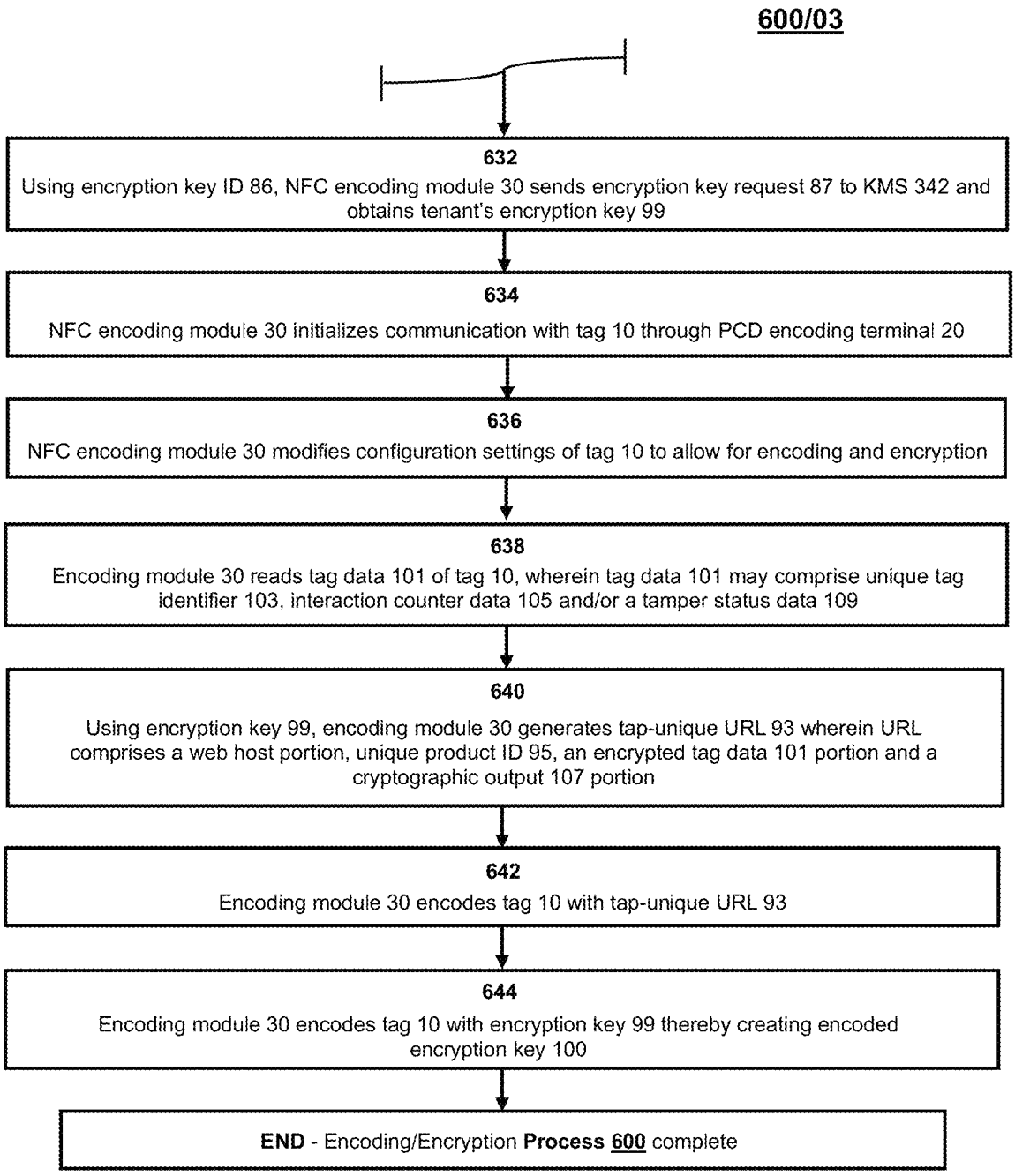

600/03
632
Using encryption key ID 86, NFC encoding module 30 sends encryption key request 87 to KMS 342 and obtains tenant's encryption key 99
634
NFC encoding module 30 initializes communication with tag 10 through PCD encoding terminal 20
636
NFC encoding module 30 modifies configuration settings of tag 10 to allow for encoding and encryption
638
Encoding module 30 reads tag data 101 of tag 10, wherein tag data 101 may comprise unique tag identifier 103, interaction counter data 105 and/or a tamper status data 109
640
Using encryption key 99, encoding module 30 generates tap-unique URL 93 wherein URL comprises a web host portion, unique product ID 95, an encrypted tag data 101 portion and a cryptographic output 107 portion
642
Encoding module 30 encodes tag 10 with tap-unique URL 93
644
Encoding module 30 encodes tag 10 with encryption key 99 thereby creating encoded encryption key 100
END - Encoding/Encryption Process 600 complete

FIG. 6C

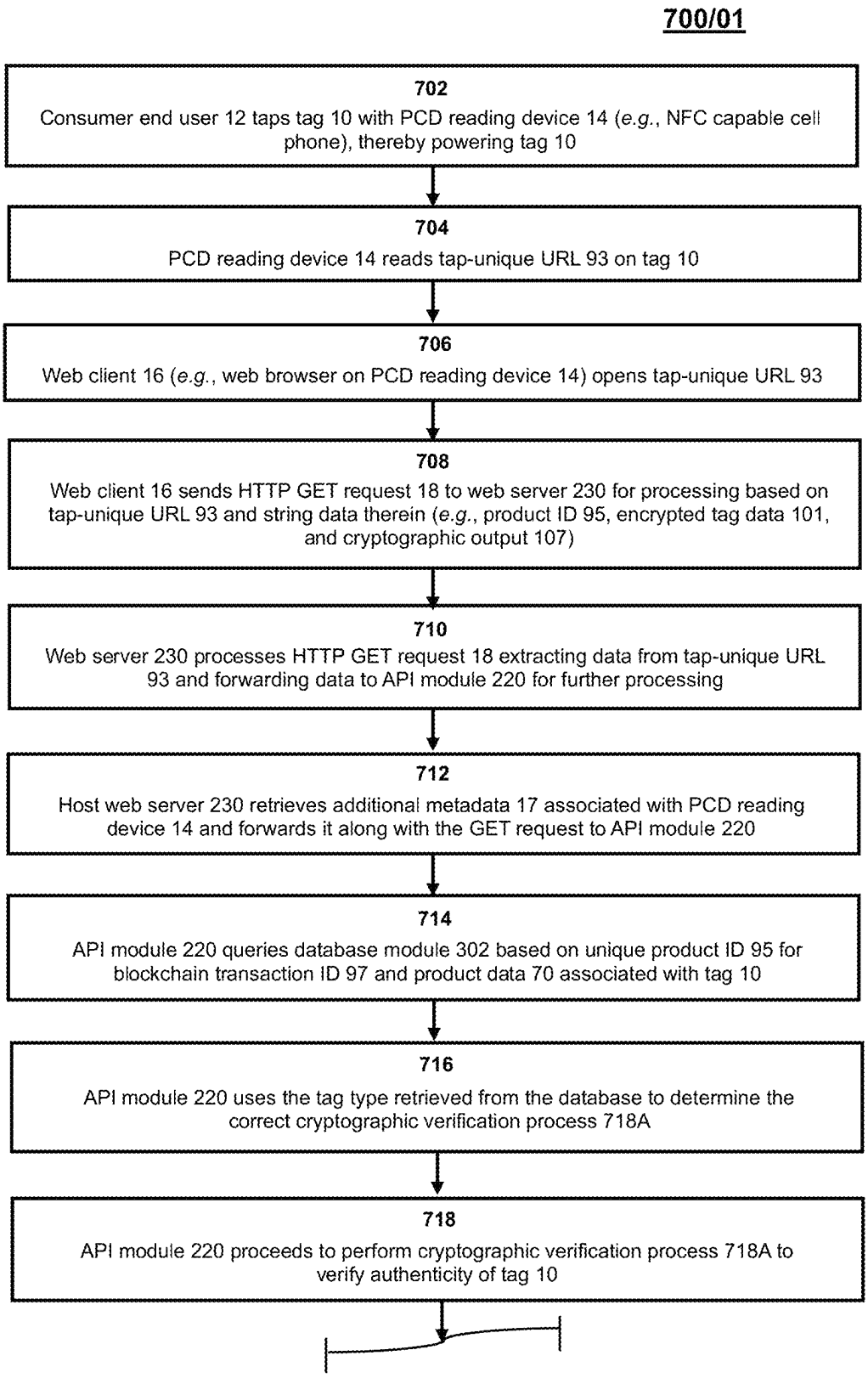

700/01
702
Consumer end user 12 taps tag 10 with PCD reading device 14 (e.g., NFC capable cell phone), thereby powering tag 10
704
PCD reading device 14 reads tap-unique URL 93 on tag 10
706
Web client 16 (e.g., web browser on PCD reading device 14) opens tap-unique URL 93
708
Web client 16 sends HTTP GET request 18 to web server 230 for processing based on tap-unique URL 93 and string data therein (e.g., product ID 95, encrypted tag data 101, and cryptographic output 107)
710
Web server 230 processes HTTP GET request 18 extracting data from tap-unique URL 93 and forwarding data to API module 220 for further processing
712
Host web server 230 retrieves additional metadata 17 associated with PCD reading device 14 and forwards it along with the GET request to API module 220
714
API module 220 queries database module 302 based on unique product ID 95 for blockchain transaction ID 97 and product data 70 associated with tag 10
716
API module 220 uses the tag type retrieved from the database to determine the correct cryptographic verification process 718A
718
API module 220 proceeds to perform cryptographic verification process 718A to verify authenticity of tag 10

FIG. 7A

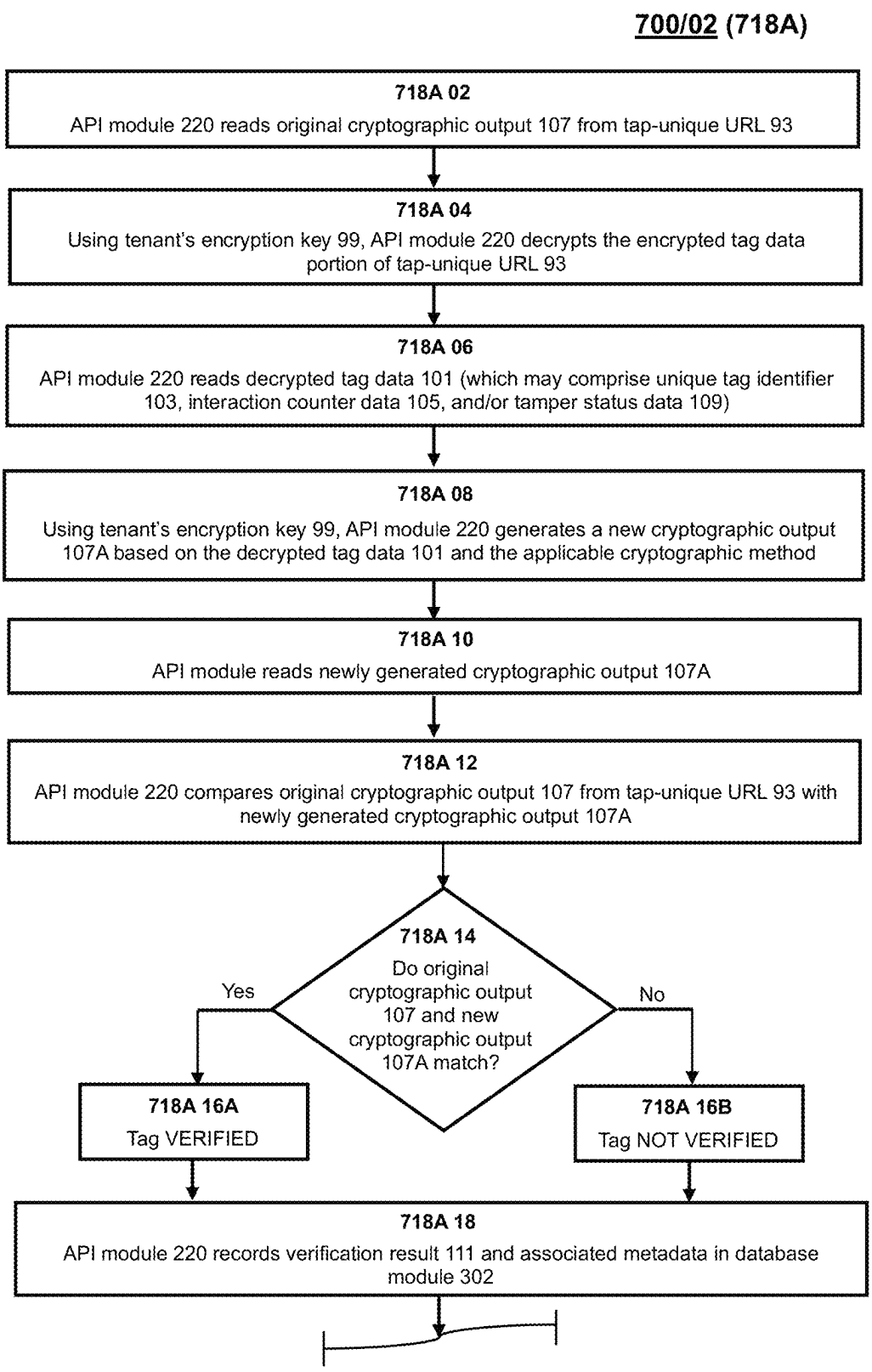

700/02 (718A)
718A 02
API module 220 reads original cryptographic output 107 from tap-unique URL 93
718A 04
Using tenant's encryption key 99, API module 220 decrypts the encrypted tag data portion of tap-unique URL 93
718A 06
API module 220 reads decrypted tag data 101 (which may comprise unique tag identifier 103, interaction counter data 105, and/or tamper status data 109)
718A 08
Using tenant's encryption key 99, API module 220 generates a new cryptographic output 107A based on the decrypted tag data 101 and the applicable cryptographic method
718A 10
API module reads newly generated cryptographic output 107A
718A 12
API module 220 compares original cryptographic output 107 from tap-unique URL 93 with newly generated cryptographic output 107A
718A 14
Do original cryptographic output 107 and new cryptographic output 107A match?
Yes
No
718A 16A
Tag VERIFIED
718A 16B
Tag NOT VERIFIED
718A 18
API module 220 records verification result 111 and associated metadata in database module 302

FIG. 7B

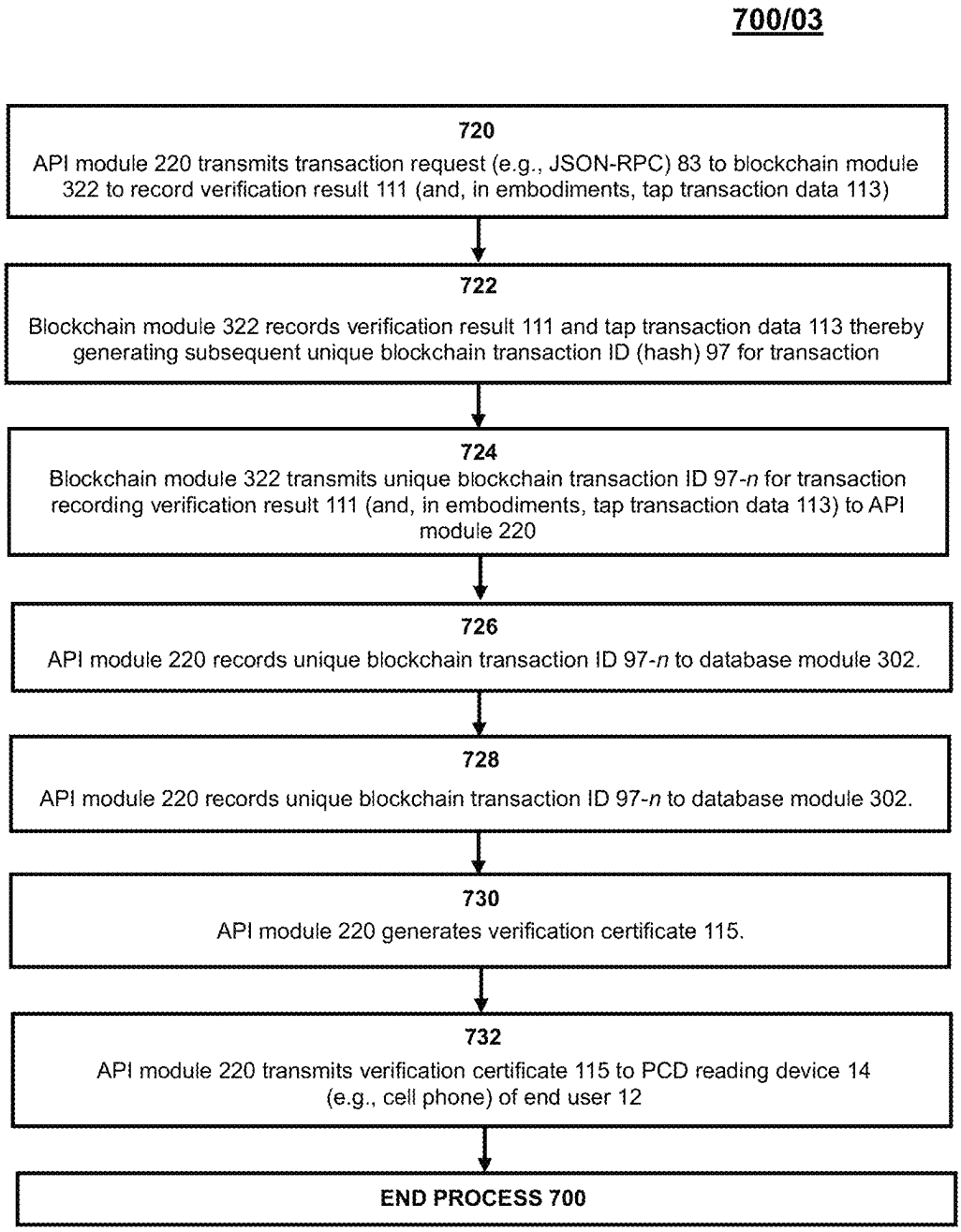

700/03
720
API module 220 transmits transaction request (e.g., JSON-RPC) 83 to blockchain module 322 to record verification result 111 (and, in embodiments, tap transaction data 113)
722
Blockchain module 322 records verification result 111 and tap transaction data 113 thereby generating subsequent unique blockchain transaction ID (hash) 97 for transaction
724
Blockchain module 322 transmits unique blockchain transaction ID 97-n for transaction recording verification result 111 (and, in embodiments, tap transaction data 113) to API module 220
726
API module 220 records unique blockchain transaction ID 97-n to database module 302.
728
API module 220 records unique blockchain transaction ID 97-n to database module 302.
730
API module 220 generates verification certificate 115.
732
API module 220 transmits verification certificate 115 to PCD reading device 14 (e.g., cell phone) of end user 12
END PROCESS 700

FIG. 7C

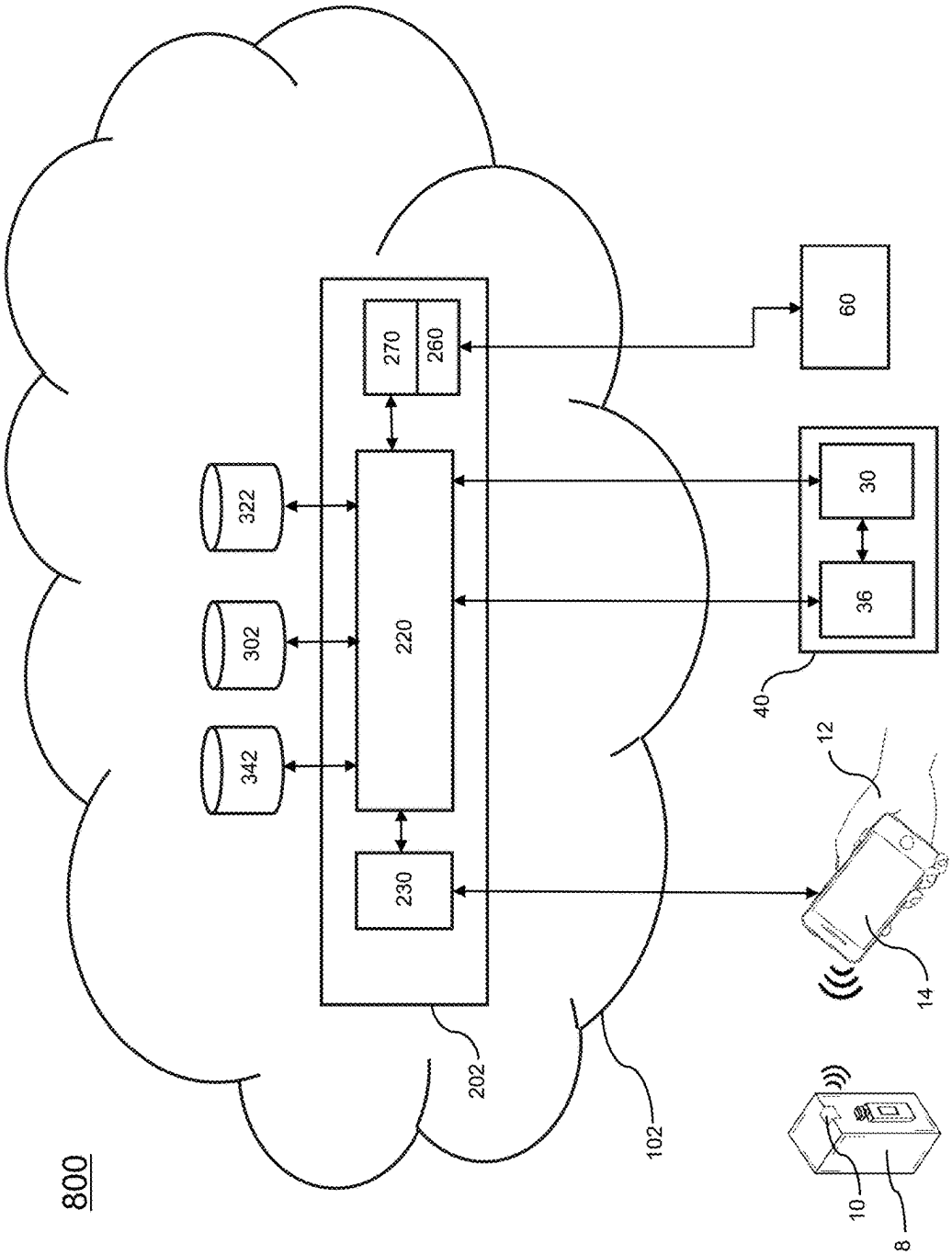


FIG. 8

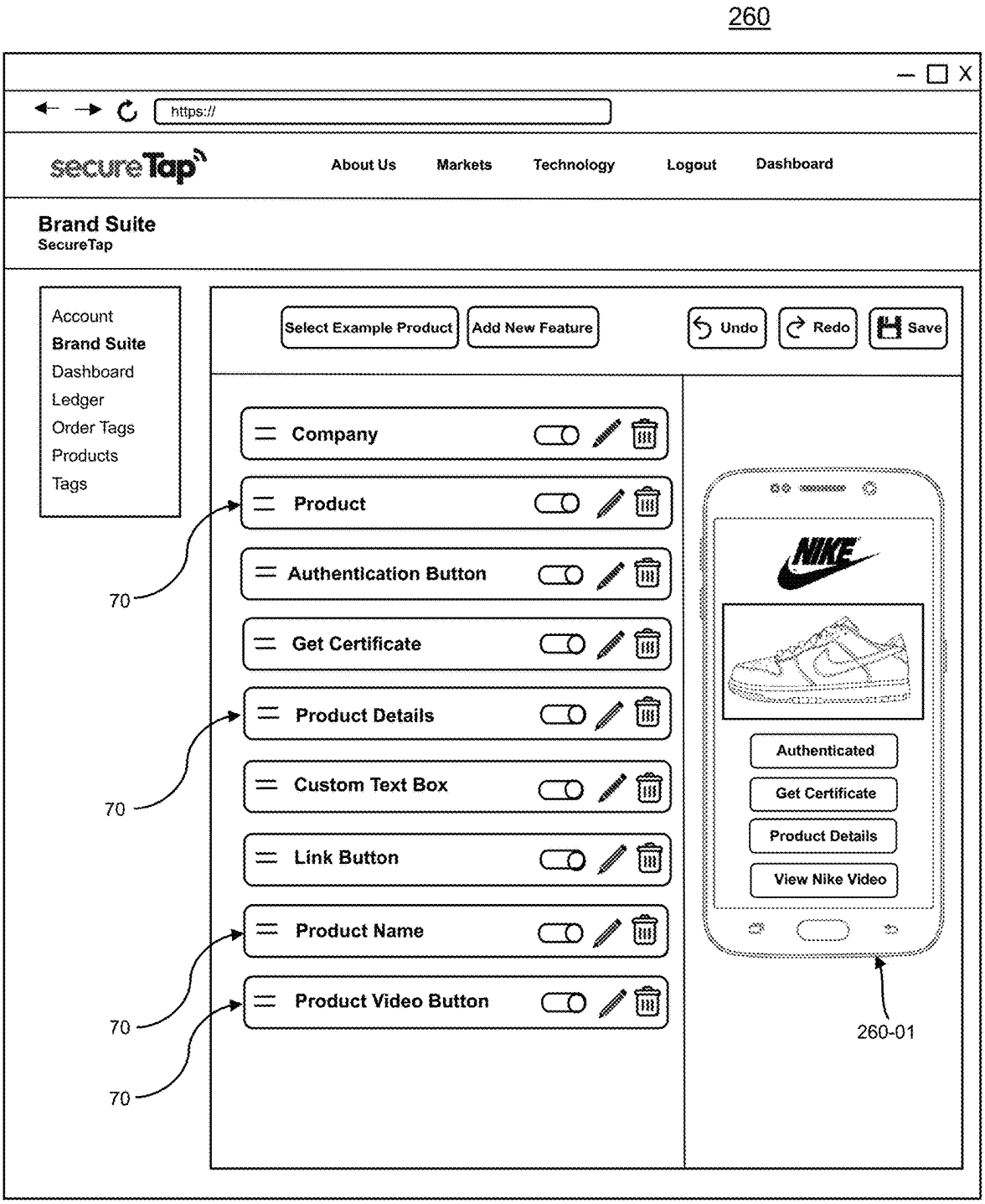
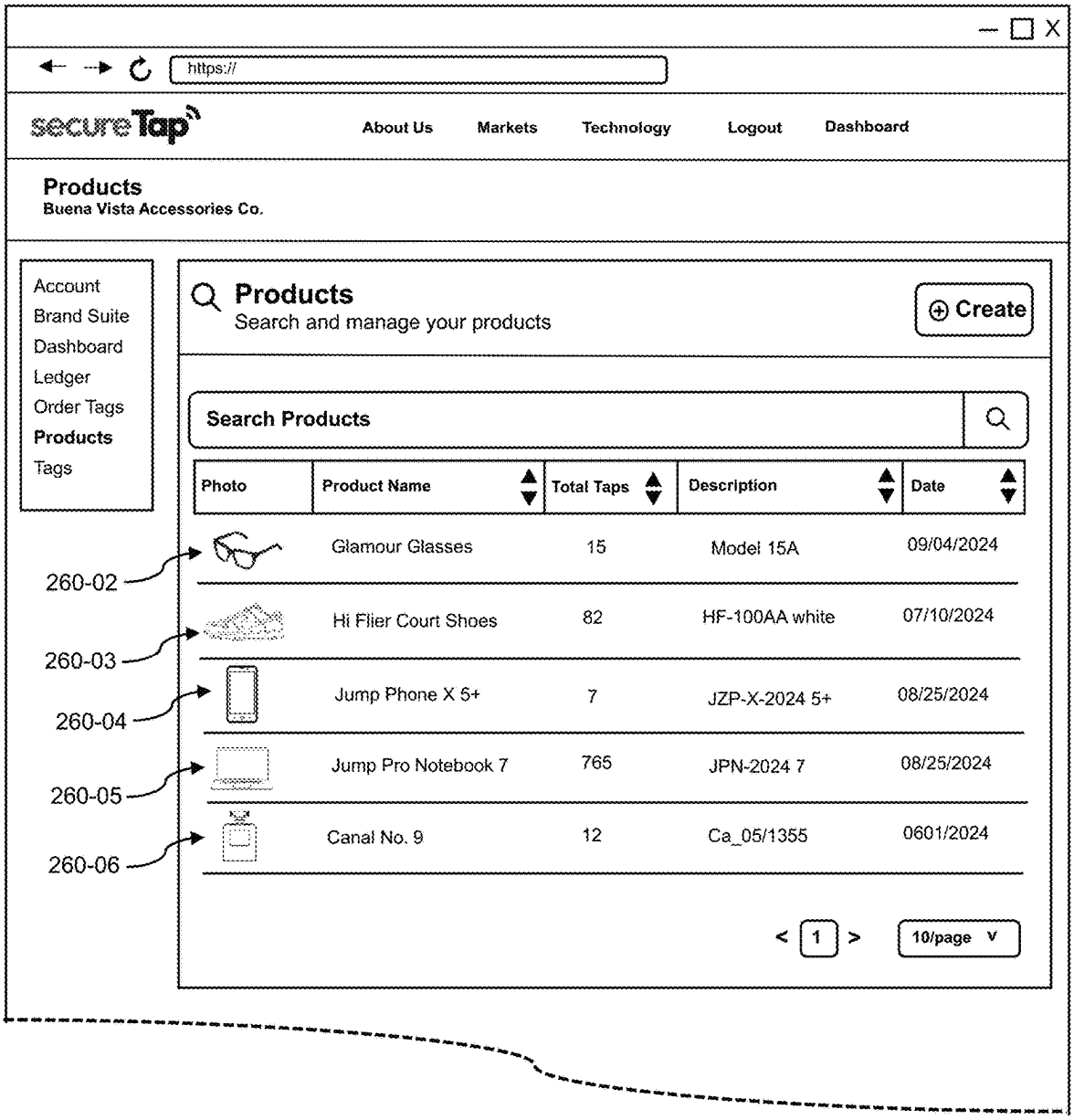

260
https://
secureTap
About Us
Markets
Technology
Logout
Dashboard
Brand Suite
SecureTap
Account
Brand Suite
Dashboard
Ledger
Order Tags
Products
Tags
Select Example Product
Add New Feature
Undo
Redo
Save
Company
Product
Authentication Button
Get Certificate
Product Details
Custom Text Box
Link Button
Product Name
Product Video Button
70
70
70
70
Authenticated
Get Certificate
Product Details
View Nike Video
260-01

FIG. 9

260


https://
secureTap
About Us
Markets
Technology
Logout
Dashboard
Products
Buena Vista Accessories Co.
Account
Brand Suite
Dashboard
Ledger
Order Tags
Products
Tags
Products
Search and manage your products
Create
Search Products
Photo
Product Name
Total Taps
Description
Date
260-02
Glamour Glasses
15
Model 15A
09/04/2024
260-03
Hi Flier Court Shoes
82
HF-100AA white
07/10/2024
260-04
Jump Phone X 5+
7
JZP-X-2024 5+
08/25/2024
260-05
Jump Pro Notebook 7
765
JPN-2024 7
08/25/2024
260-06
Canal No. 9
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0601/2024
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FIG. 10

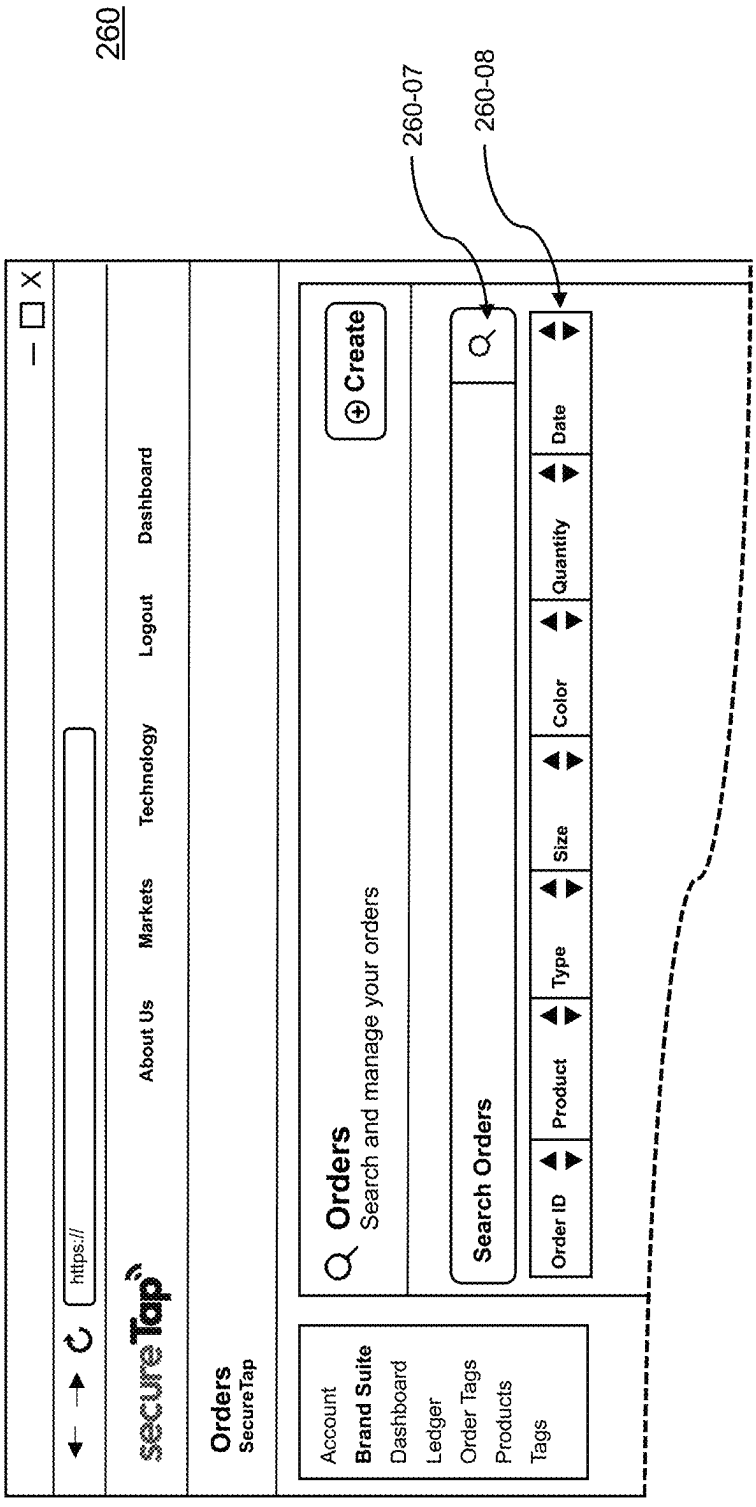

260
260-07
260-08
secureTap
https://
About Us
Markets
Technology
Logout
Dashboard
Orders
SecureTap
Account
Brand Suite
Dashboard
Ledger
Order Tags
Products
Tags
Orders
Search and manage your orders
Create
Search Orders
Order ID
Product
Type
Size
Color
Quantity
Date

FIG. 11

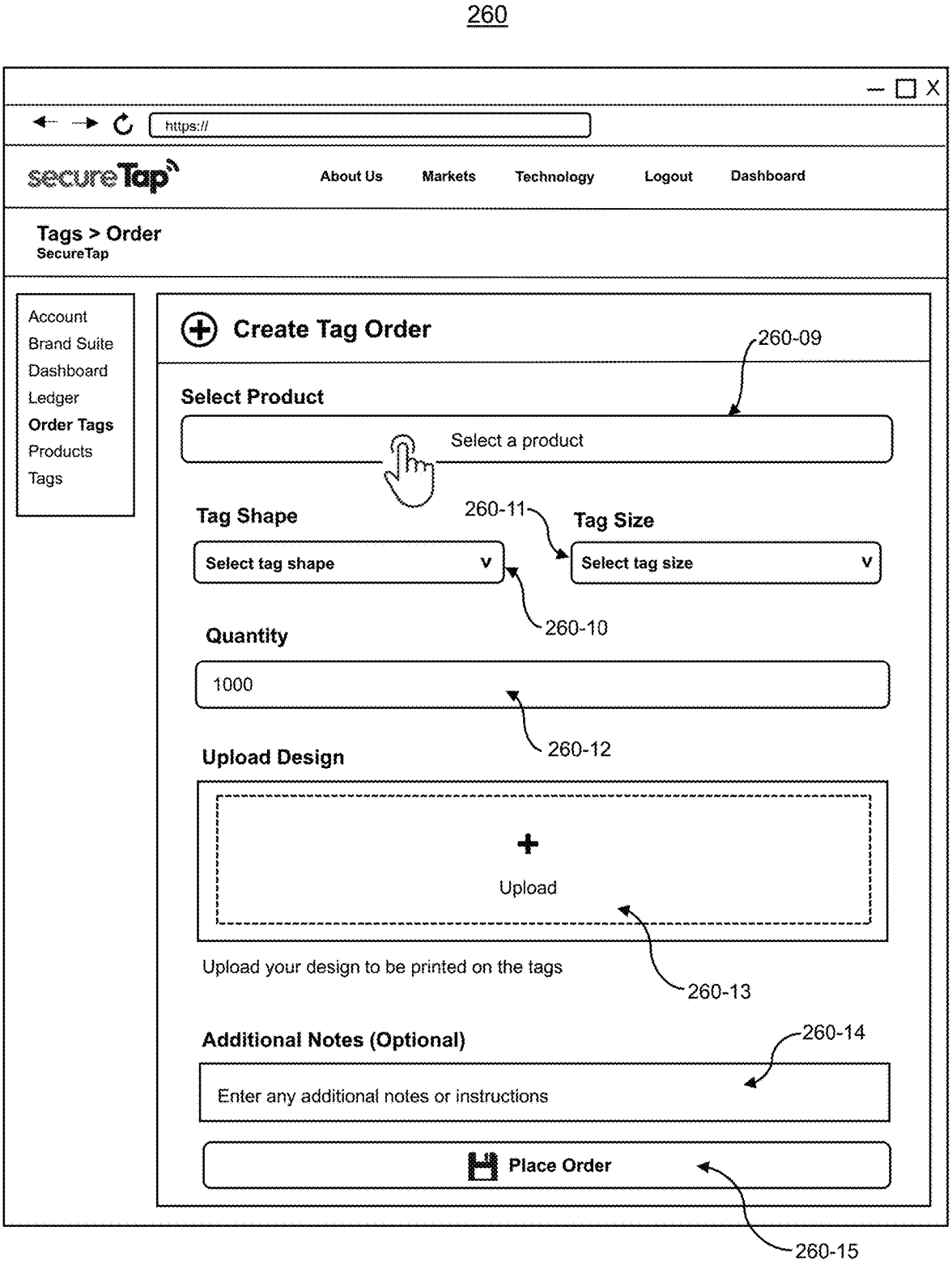

260
https://
secureTap
About Us
Markets
Technology
Logout
Dashboard
Tags > Order
SecureTap
Account
Brand Suite
Dashboard
Ledger
Order Tags
Products
Tags
Create Tag Order
260-09
Select Product
Select a product
Tag Shape
260-11
Tag Size
Select tag shape
Select tag size
260-10
Quantity
1000
260-12
Upload Design
Upload
Upload your design to be printed on the tags
260-13
Additional Notes (Optional)
260-14
Enter any additional notes or instructions
Place Order
260-15

FIG. 12

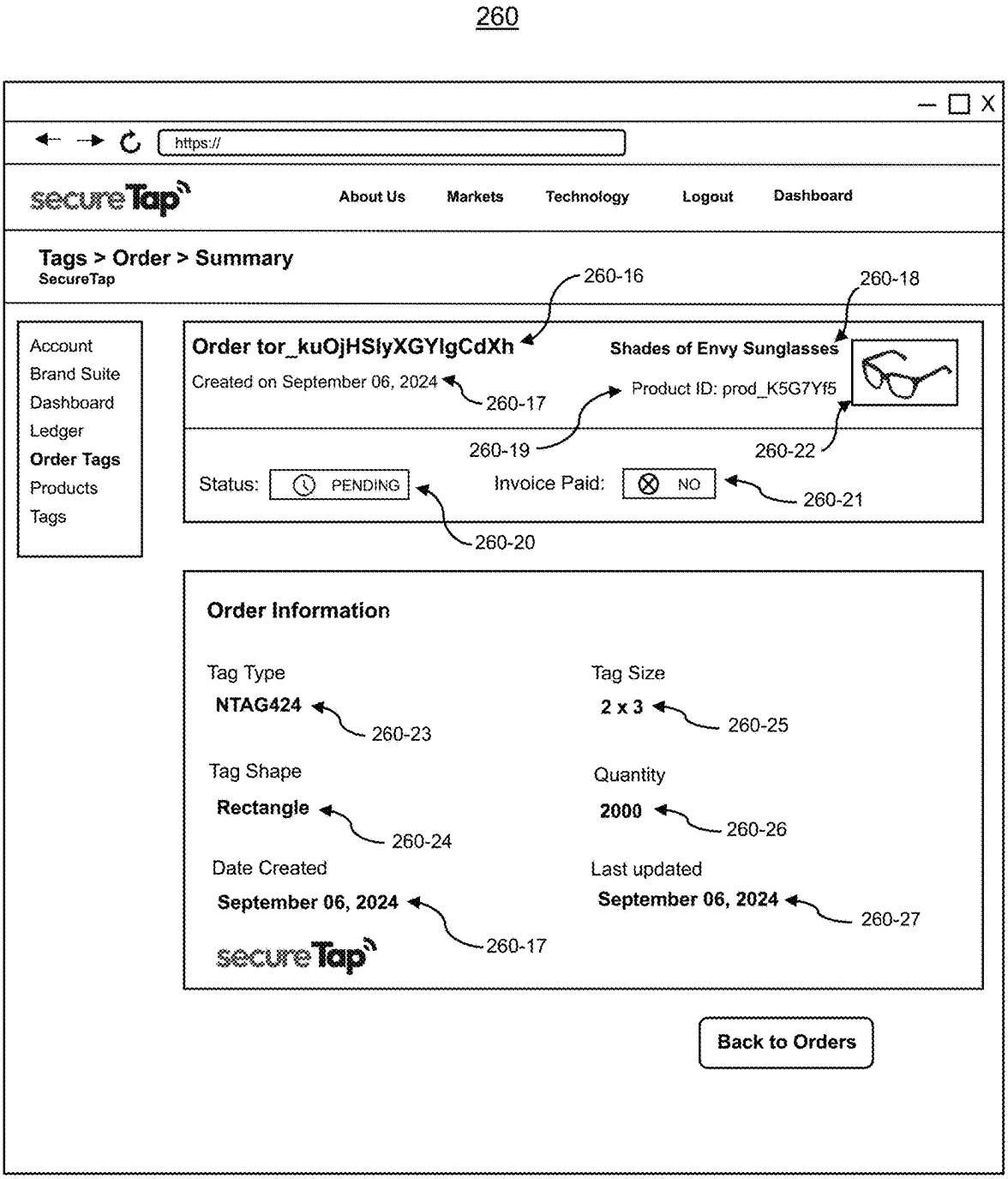

260
https://
secureTap
About Us
Markets
Technology
Logout
Dashboard
Tags > Order > Summary
SecureTap
260-16
260-18
Account
Brand Suite
Dashboard
Ledger
Order Tags
Products
Tags
Order tor_kuOjHSlyXGYlgCdXh
Shades of Envy Sunglasses
Created on September 06, 2024
260-17
Product ID: prod_K5G7Yf5
260-19
260-22
Status:
PENDING
Invoice Paid:
NO
260-21
260-20
Order Information
Tag Type
NTAG424
260-23
Tag Size
2 x 3
260-25
Tag Shape
Rectangle
260-24
Quantity
2000
260-26
Date Created
September 06, 2024
260-17
Last updated
September 06, 2024
260-27
secureTap
Back to Orders

FIG. 13

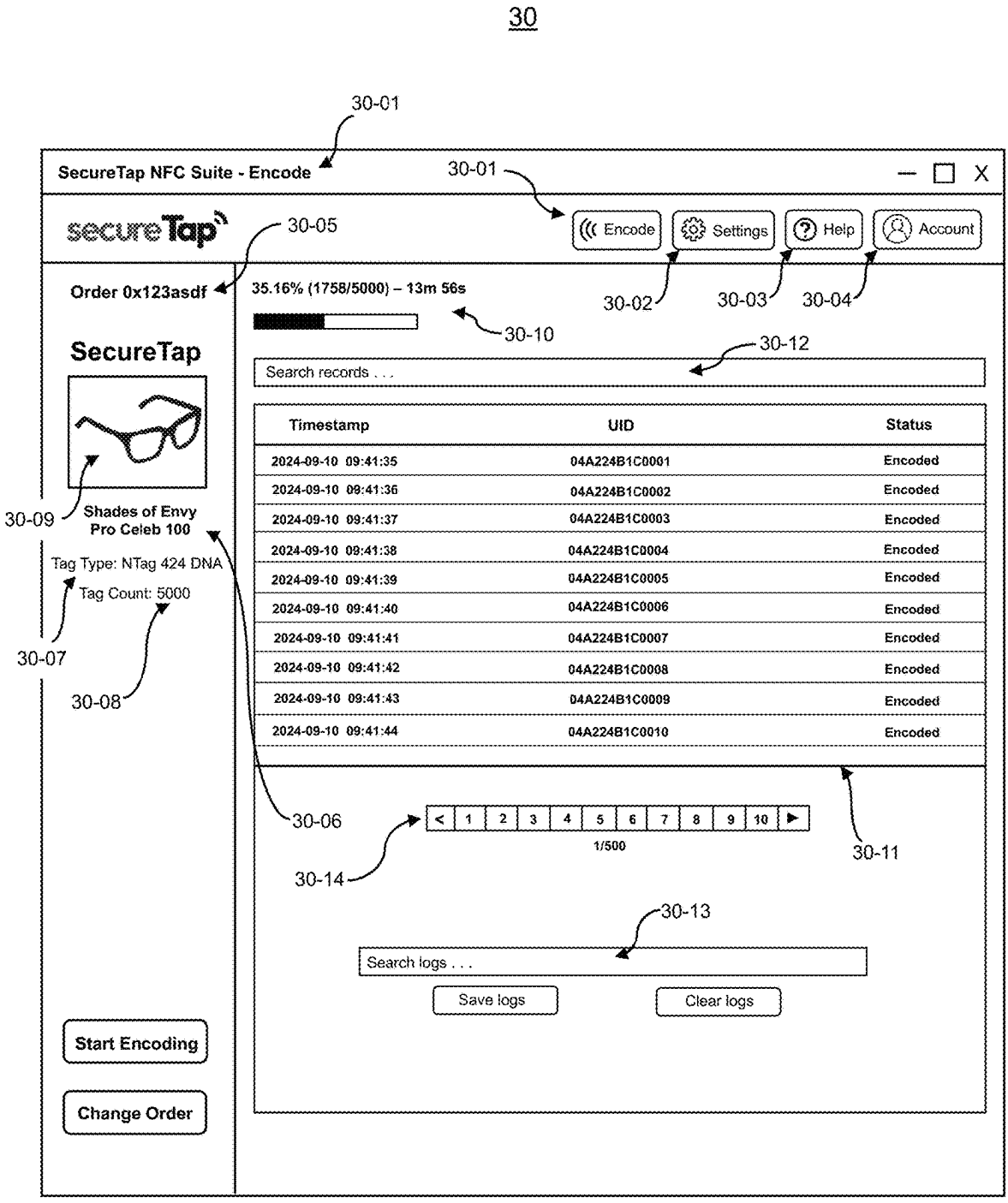

30
30-01
SecureTap NFC Suite - Encode
30-01
Encode
Settings
Help
Account
30-02
30-03
30-04
30-05
Order 0x123asdf
35.16% (1758/5000) – 13m 56s
30-10
30-12
Search records . . .
SecureTap
Timestamp
UID
Status
2024-09-10 09:41:35 04A224B1C0001 Encoded
2024-09-10 09:41:36 04A224B1C0002 Encoded
2024-09-10 09:41:37 04A224B1C0003 Encoded
2024-09-10 09:41:38 04A224B1C0004 Encoded
2024-09-10 09:41:39 04A224B1C0005 Encoded
2024-09-10 09:41:40 04A224B1C0006 Encoded
2024-09-10 09:41:41 04A224B1C0007 Encoded
2024-09-10 09:41:42 04A224B1C0008 Encoded
2024-09-10 09:41:43 04A224B1C0009 Encoded
2024-09-10 09:41:44 04A224B1C0010 Encoded
30-09
Shades of Envy
Pro Celeb 100
Tag Type: NTag 424 DNA
Tag Count: 5000
30-07
30-08
30-06
< 1 2 3 4 5 6 7 8 9 10 >
1/500
30-14
30-11
30-13
Search logs . . .
Save logs
Clear logs
Start Encoding
Change Order

FIG. 14

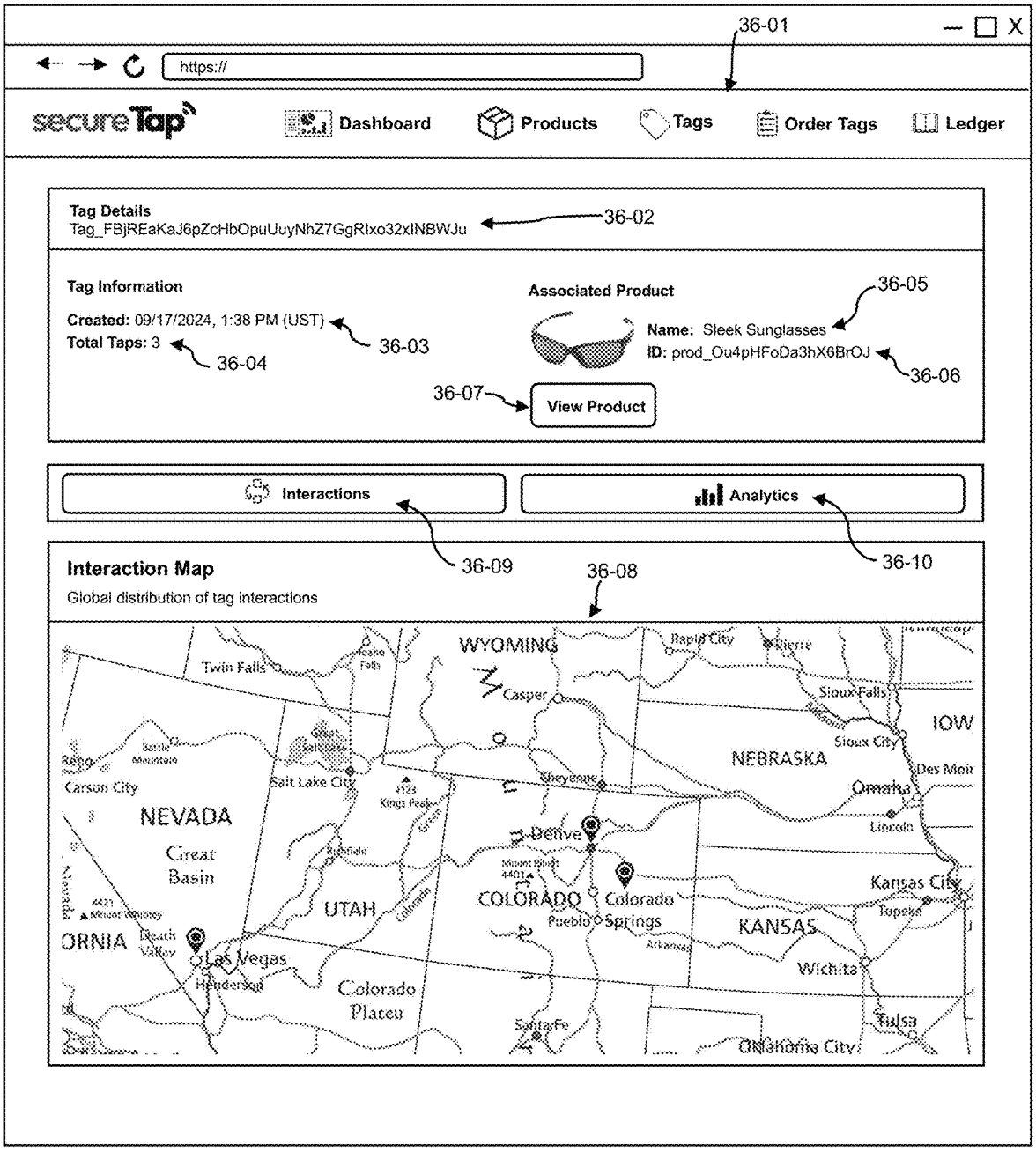

36
36-01
https://
secureTap
Dashboard
Products
Tags
Order Tags
Ledger
Tag Details
Tag_FBjREaKaJ6pZcHbOpuUuyNhZ7GgRIxo32xINBWJu
36-02
Tag Information
Created: 09/17/2024, 1:38 PM (UST)
36-03
Total Taps: 3
36-04
Associated Product
36-05
Name: Sleek Sunglasses
ID: prod_Ou4pHFoDa3hX6BrOJ
36-06
36-07
View Product
Interactions
Analytics
36-09
36-10
Interaction Map
Global distribution of tag interactions
36-08
WYOMING
Twin Falls
Casper
Rapid City
Pierre
Sioux Falls
Sioux City
NEBRASKA
Omaha
Lincoln
Des Moi
Salt Lake City
Cheyenne
Carson City
NEVADA
Great Basin
Denve
COLORADO
Colorado Springs
Pueblo
UTAH
KANSAS
Kansas City
Topeka
Wichita
Las Vegas
Henderson
Colorado Plateu
Santa Fe
Tulsa
Oklahoma City

FIG. 15

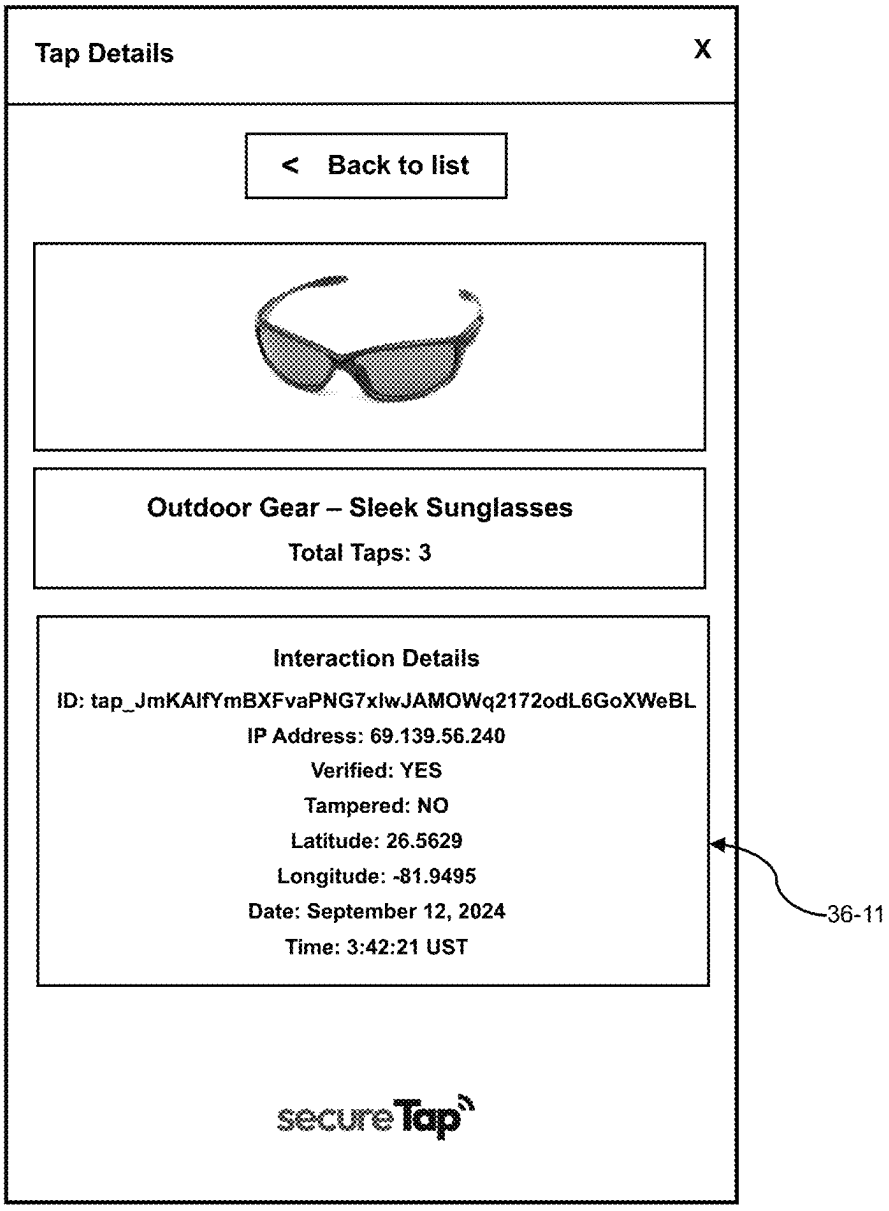

Tap Details
X
< Back to list
Outdoor Gear – Sleek Sunglasses
Total Taps: 3
Interaction Details
ID: tap_JmKAlfYmBXFvaPNG7xlwJAMOWq2172odL6GoXWeBL
IP Address: 69.139.56.240
Verified: YES
Tampered: NO
Latitude: 26.5629
Longitude: -81.9495
Date: September 12, 2024
Time: 3:42:21 UST
secureTap
36-11

FIG. 16

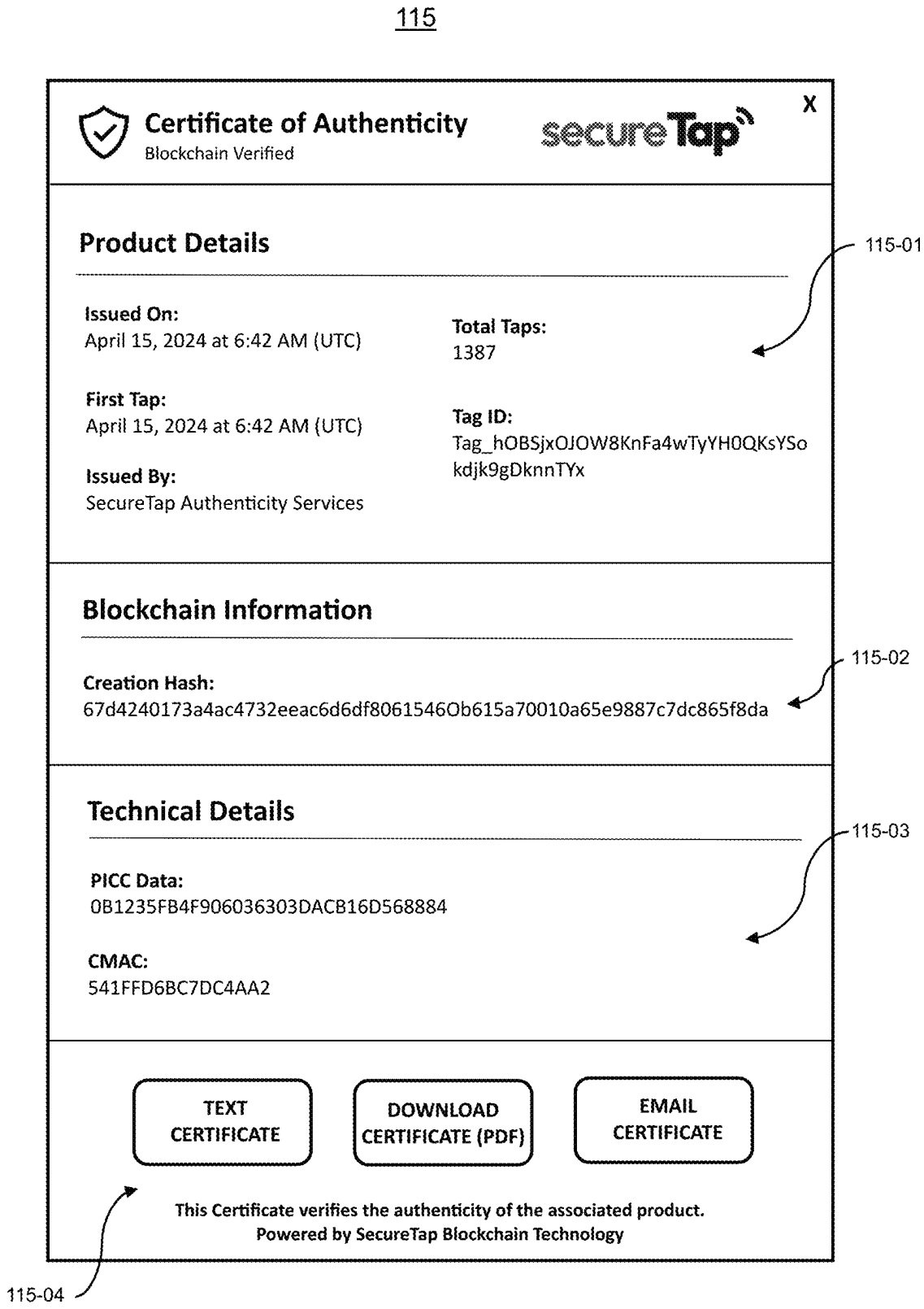

115
Certificate of Authenticity
Blockchain Verified
secureTap
X
Product Details
115-01
Issued On:
April 15, 2024 at 6:42 AM (UTC)
Total Taps:
1387
First Tap:
April 15, 2024 at 6:42 AM (UTC)
Tag ID:
Tag_hOBSjxOJOW8KnFa4wTyYH0QKsYSo
kdjk9gDknnTYx
Issued By:
SecureTap Authenticity Services
Blockchain Information
115-02
Creation Hash:
67d4240173a4ac4732eeac6d6df8061546Ob615a70010a65e9887c7dc865f8da
Technical Details
115-03
PICC Data:
0B1235FB4F906036303DACB16D568884
CMAC:
541FFD6BC7DC4AA2
TEXT CERTIFICATE
DOWNLOAD CERTIFICATE (PDF)
EMAIL CERTIFICATE
This Certificate verifies the authenticity of the associated product.
Powered by SecureTap Blockchain Technology
115-04

FIG. 17

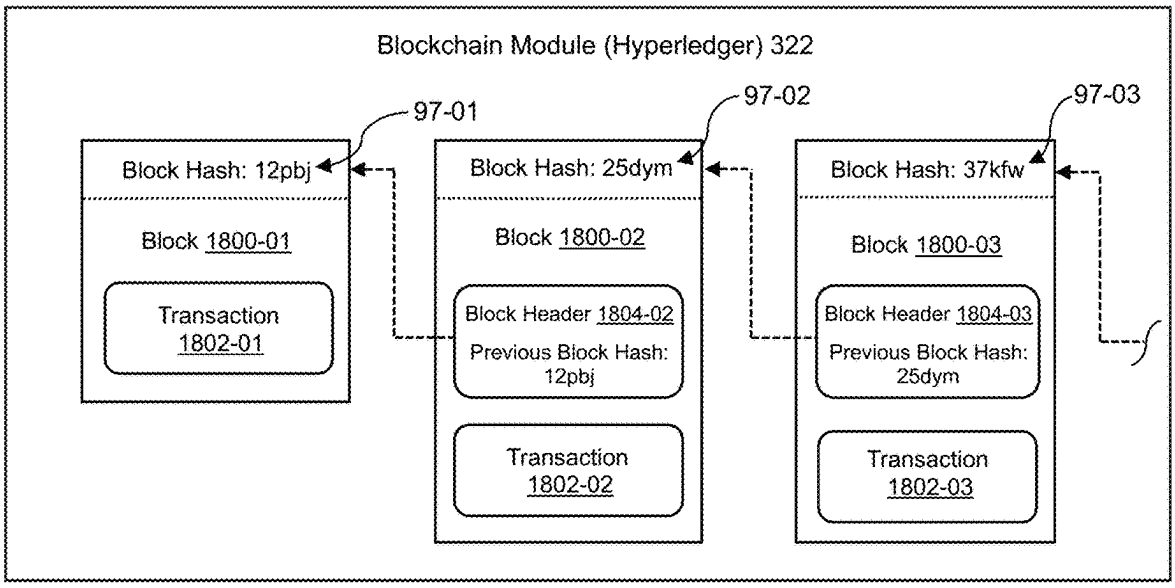

Blockchain Module (Hyperledger) 322
97-01
97-02
97-03
Block Hash: 12pbj
Block Hash: 25dym
Block Hash: 37kfw
Block 1800-01
Block 1800-02
Block 1800-03
Transaction 1802-01
Block Header 1804-02
Previous Block Hash: 12pbj
Block Header 1804-03
Previous Block Hash: 25dym
Transaction 1802-02
Transaction 1802-03

FIG. 18

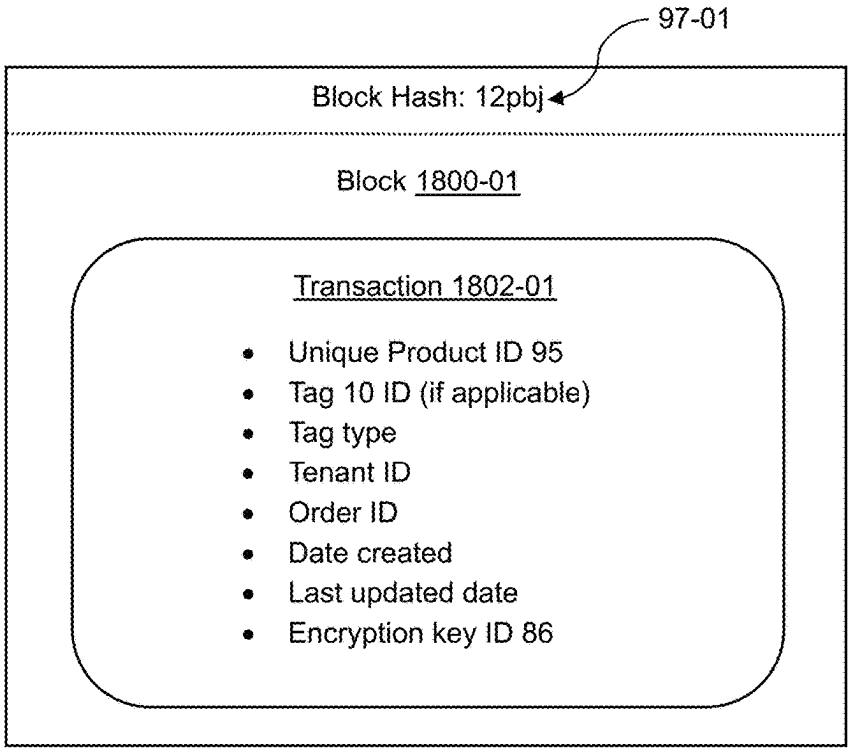

97-01
Block Hash: 12pbj
Block 1800-01
Transaction 1802-01
Unique Product ID 95
Tag 10 ID (if applicable)
Tag type
Tenant ID
Order ID
Date created
Last updated date
Encryption key ID 86

FIG. 19

Simplified SQL statement for the `interactions` (tap data) table:

```
CREATE TABLE interactions (
    id            VARCHAR(255) PRIMARY KEY,
    tag_id        VARCHAR(255) NOT NULL,
    date_created  TIMESTAMP NOT NULL,
    last_updated  TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    ip_address    VARCHAR(255) NOT NULL,
    metadata      TEXT,
    is_verified   BOOLEAN NOT NULL,
    is_tampered   BOOLEAN NOT NULL,
    latitude      DOUBLE PRECISION,
    longitude     DOUBLE PRECISION,
    FOREIGN KEY (tag_id) REFERENCES tags(id) ON DELETE CASCADE
   );
```

FIG. 20

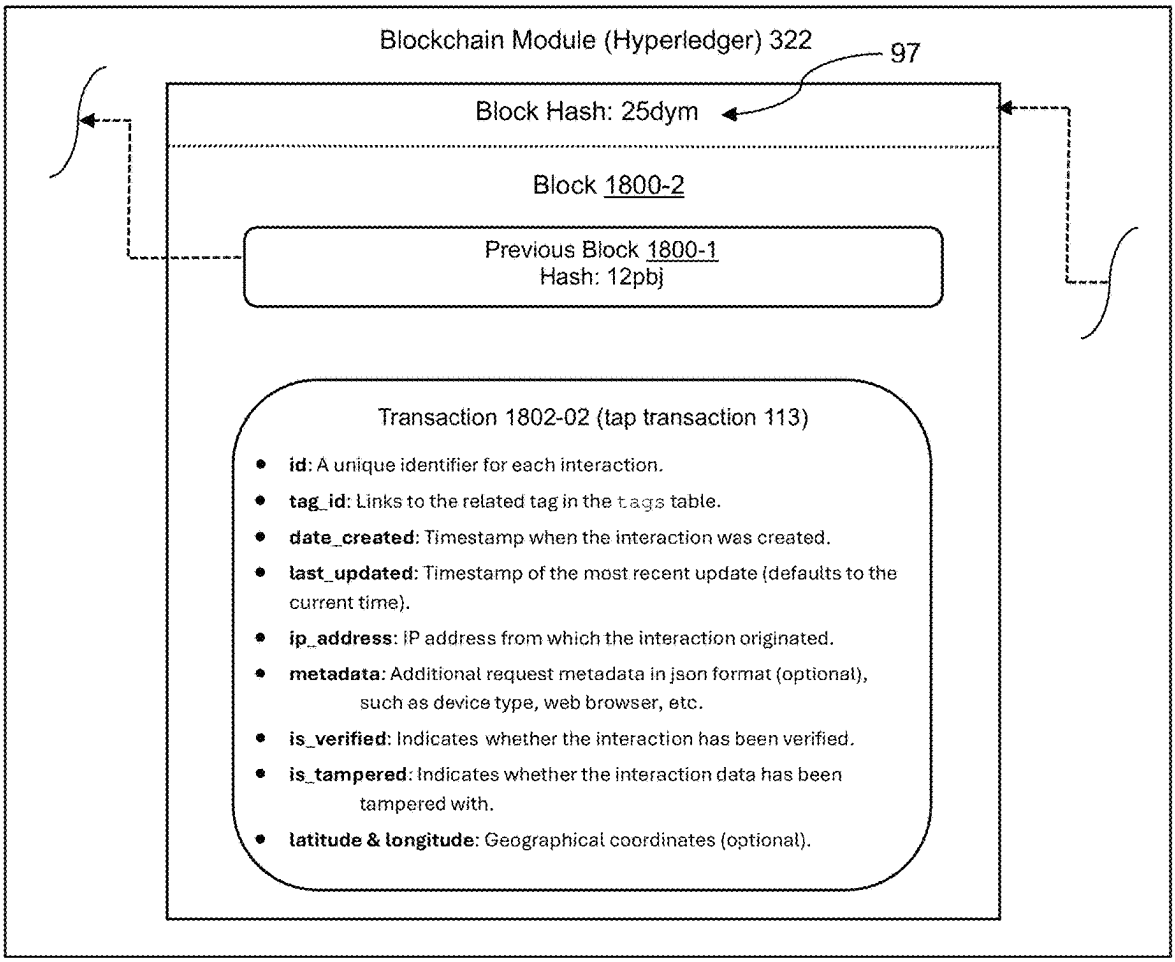


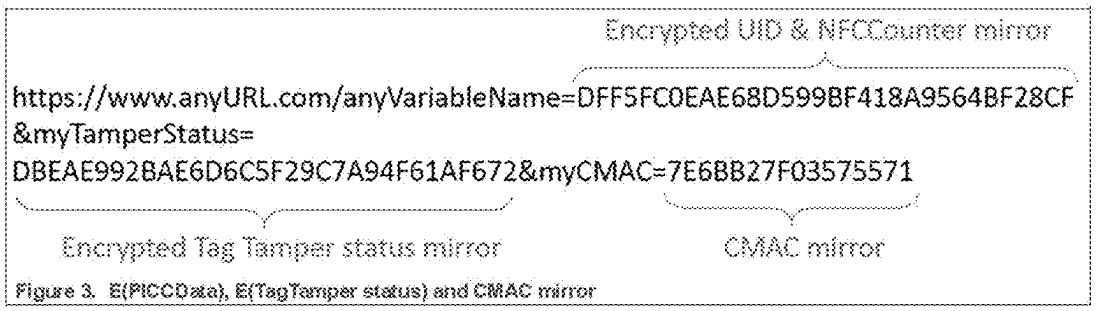
FIG. 21



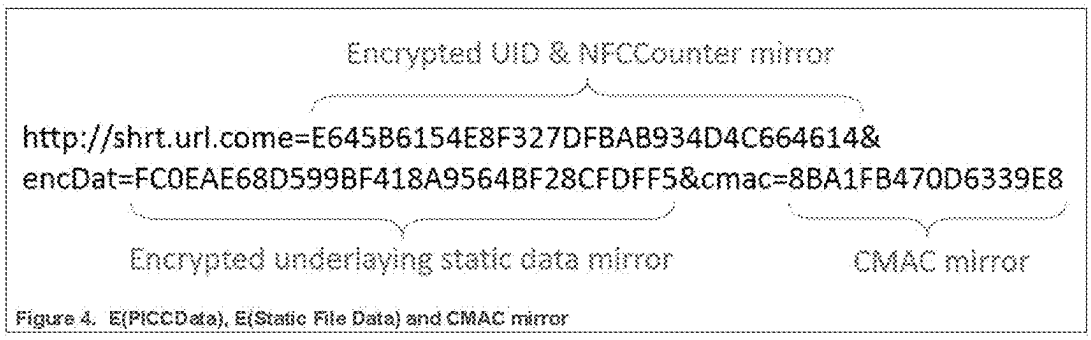
Example 1
(AN12196 NXP Document, Figure 1, page 8)



Example 2
(AN12196 NXP Document, Figure 2, page 8)



Example 3
(AN12196 NXP Document, Figure 3, page 8)



Example 4
(AN12196 NXP Document, Figure 4, page 8)

FIG. 22

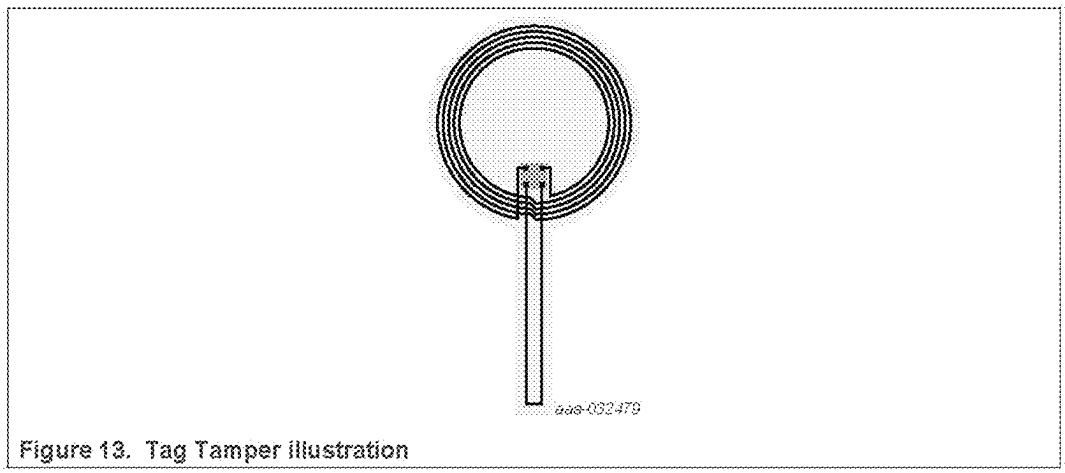


Figure 13. Tag Tamper illustration

Example 5
(NT4H2421Tx Document, Figure 13, page 48)

FIG. 23

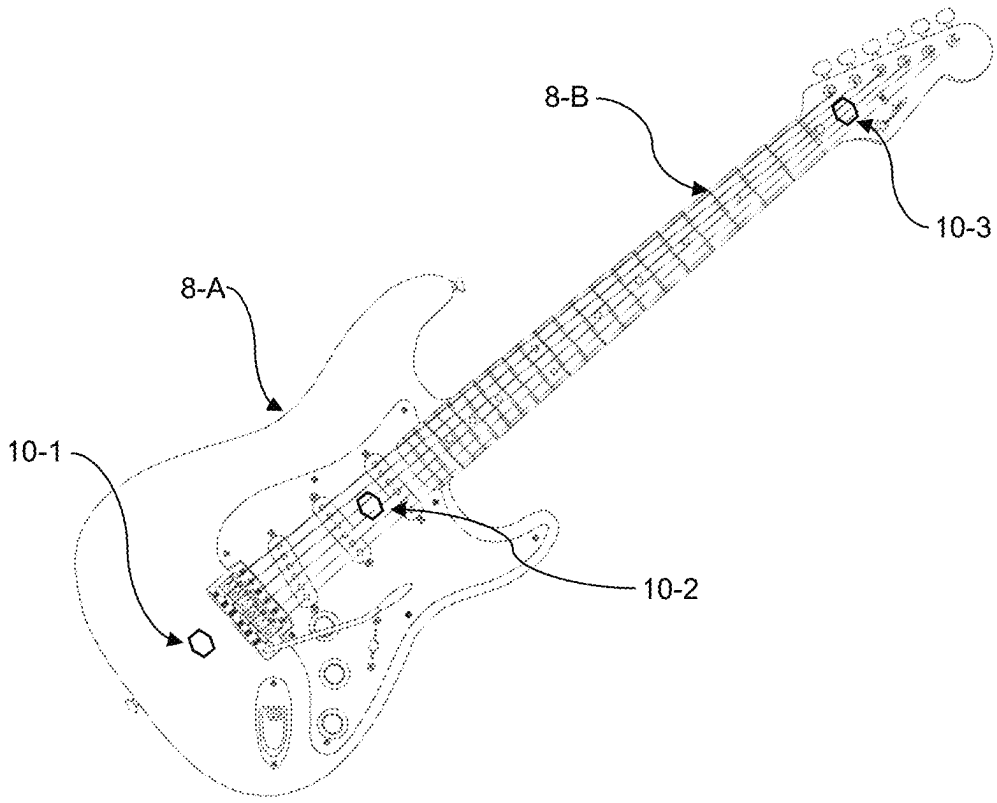


FIG. 24

SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION

PRIORITY CLAIMS

This application is a Continuation of U.S. Non-Provisional application Ser. No. 19/017,891, "SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION," filed on Jan. 13, 2025, and claims the benefit of that application, the entire disclosure of which is incorporated by reference herein, in its entirety, for all purposes, including any and all claims of priority made therein and as further made in the Application Data Sheet filed with respect to that application. U.S. Non-Provisional application Ser. No. 19/017,891 further claims the benefit of U.S. Provisional Application No. 63/555,458, "SYSTEM AND METHOD OF AUTHENTICATING GOODS AND PRODUCTS," filed on Feb. 20, 2024, U.S. Provisional Application No. 63/680,113, "SECURE AUTHENTICATION AND ASSET MANAGEMENT SYSTEM USING BLOCKCHAIN TECHNOLOGY," filed on Aug. 7, 2024, and U.S. Provisional Application No. 63/716,270, "SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION," filed on Nov. 5, 2024, and therefore this application claims the benefit of all those applications, the entire disclosures of which are incorporated by reference herein, in their entirety, for all purposes.

FIELD OF INVENTION

The invention relates to, among other applications, a system, method and process for product authentication and verification using Near Field Communication (NFC), blockchain technology (Hyperledger), cryptography, and related technologies. More specifically, the invention relates to a secure system for authenticating and managing products using NFC technology integrated with a Java and SQL built API, and a transaction fee-free private blockchain, Hyperledger. The system ensures product authenticity, combats counterfeiting, and enhances security, transparency, and traceability in supply chains.

RELATED APPLICATIONS

This application is a Continuation of U.S. Non-Provisional application Ser. No. 19/017,891, "SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION," filed on Jan. 13, 2025, and claims the benefit of that application, the entire disclosure of which is incorporated by reference herein, in its entirety, for all purposes. U.S. Non-Provisional application Ser. No. 19/017,891 further claims the benefit of U.S. Provisional Application No. 63/555,458, "SYSTEM AND METHOD OF AUTHENTICATING GOODS AND PRODUCTS," filed on Feb. 20, 2024; U.S. Provisional Application No. 63/680,113, "SECURE AUTHENTICATION AND ASSET MANAGEMENT SYSTEM USING BLOCKCHAIN TECHNOLOGY," filed on Aug. 7, 2024; and U.S. Provisional Application No. 63/716,270, "SYSTEM, METHOD AND PROCESS FOR PRODUCT AUTHENTICATION AND VERIFICATION," filed on Nov. 5, 2024, and therefore this application claims the benefit of all those applications, the entire disclosures of which are incorporated by reference herein, in their entirety, for all purposes.

SUMMARY OF THE INVENTION

The invention relates to, among other applications, a system, method and process for product authentication and verification using Near Field Communication (NFC) technology, blockchain technology (Hyperledger), cryptography, and related technologies. More specifically, the invention relates to a secure system for authenticating and managing assets using NFC technology integrated with a Java and SQL built API, and a transaction fee-free private blockchain, Hyperledger. The system ensures product authenticity, combats counterfeiting, and enhances security, transparency, and traceability in supply chains. Combining NFC technology, blockchain, and a proprietary API, the invention creates a tamper-proof system for verifying product authenticity.

In embodiments, a unique product identifier is generated for a unique individual product and incorporated into a data structure for that product. In embodiments, the unique product identifier serves as a common data element that links the unique individual product and to a corresponding, respective unique individual NFC tag to be encoded and affixed to the product. Upon generation of the data structure for the unique individual product, wherein the data structure comprises at least the unique product identifier, a request is transmitted to a blockchain to record the data structure. The blockchain records the data structure, thereby generating an initial unique blockchain identifier (hash) for that transaction, which is then transmitted in response to the request. The initial unique blockchain identifier is recorded to the data structure for the product, thereby updating the data structure dynamically, and in the process, directly associating the initial unique blockchain identifier with the unique product identifier. In embodiments, the data structure may be recorded to a database.

Continuing, an appropriate NFC tag is encoded with a tap-unique URL that comprises the unique product identifier, thereby connecting that a specific tag with the product and further connecting the tag with the blockchain ledger established for the unique product identifier. After the tag is encoded with the tap-unique URL, wherein the URL comprises a tap-unique cryptographic output, it is affixed to its respective product. When the tag is tapped by an NFC proximity coupling device, such as, for example, an NFC-enabled cell phone, a web client operating on the device reads and opens the URL and is directed to web host whereupon the unique product identifier in the URL is read. In embodiments a verification process ensues, based on the type of cryptographic output of the URL (and the means for generating same). Based on the applicable protocols of the cryptographic verification process, a verification result is generated, wherein the tag is either verified as valid or not.

Continuing, based on the unique product identifier in the tap-unique URL, a request is transmitted to the blockchain ledger to record the verification result. In embodiments, additional tap-interaction data may be included in the request, including metadata associated with the tap interaction. The blockchain records the verification result (and other applicable data as desired), thereby generating a subsequent unique blockchain identifier (hash) for that transaction, which is then transmitted in response to the request. The subsequent unique blockchain identifier is recorded to the database from which various updated data structures for the product may be generated. In embodiments, a verification certificate comprising the verification result is transmitted back to the web client operating on the proximity coupling device for viewing by a user.

Importantly, embodiments of the invention use various appropriate NFC tags which may utilize various NFC and ISO protocols, such as, for example ISO/IEC 14443, ISO/IEC 7816, and ISO/IEC 18092, which are incorporated by reference in their entirety. It is to be understood that various NFC tags, depending on the manufacturer thereof, may utilize different cryptographic processes for encrypting portions of the tap-unique URL for the tag. Hence, while various examples of specific NFC tags and ISO standards and protocols are discussed herein, it is to be understood the invention is not dependent on any specific standard or protocol and that the invention may be implemented using any such applicable NFC, RFID or cryptographic protocol or standard, whether currently existing or that may be come about in the future.

BACKGROUND

The integration of radio frequency identification (RFID) technology with databases revolutionized industries by enabling efficient tracking and management of assets and inventory in real-time. This advancement allowed businesses to enhance operational efficiencies, reduce losses, and improve data accuracy across supply chains, retail, logistics, and beyond. By attaching NFC technology to blockchains, the present invention achieves even greater security, transparency, and immutability. Blockchain's decentralized nature ensures that data related to NFC interactions (e.g., "taps" or "tap interactions") is tamper-proof and easily verifiable, thereby enhancing trust and accountability. This leap forward not only builds on the legacy of RFID and databases, but also opens new avenues for secure, transparent, and reliable authentication and asset management in various sectors. Moreover, the widespread adoption of NFC technology in smartphones allows users to seamlessly interact with NFC tags using their devices. By tapping an NFC-enabled phone to an NFC tag affixed to a product or its packaging, users may instantly access authenticated and encrypted information stored on the blockchain, providing real-time verification of product authenticity, traceability, and other valuable data. This democratizes access to secure information, making blockchain-based authentication widely accessible to consumers and businesses alike.

BRIEF DESCRIPTION OF FIGURES

A brief description of the drawings now follows.

FIG. **1** is a schematic of a basic configuration **100** of an encoding portion of an embodiment of the invention.

FIG. **2** is a schematic depicting a tap interaction between a proximity coupling device (PCD), in this case a cell phone, and an encoded NFC tag.

FIG. **3** is a schematic depicting an alternative basic configuration of an encoding portion of an embodiment of the invention.

FIG. **4** is a perspective view of an encoded NFC tag affixed to a product.

FIG. **5** is a perspective view of an end user interacting with an encoded NFC tag affixed to a product by tapping a PCD reading device, in this case a cell or smart phone, to the encoded NFC tag.

FIGS. **6**A-**6**C depict process **600**, an encoding embodiment portion of the invention.

FIGS. **7**A-**7**C depict process **700**, a tap interaction/verification embodiment portion of the invention, including cryptographic verification process **718**A.

FIG. **8** is a schematic of a basic tap interaction/verification configuration **800** of a portion of an embodiment of the invention.

FIG. **9** depicts a sample tenant user interface of an embodiment of the invention wherein a tenant may request or order one or more encoded NFC tags for one or more products.

FIG. **10** depicts a sample tenant user interface of an embodiment of the invention wherein a tenant may review one or more products to which encoded NFC tags have been affixed and the end user tap interactions for each such tag and product.

FIG. **11** depicts a sample tenant user interface of an embodiment of the invention wherein a tenant may search for one or more tag encoding requests for one or more products.

FIG. **12** depicts a sample tenant user interface of an embodiment of the invention wherein a tenant may create a request for one or more NFC tags to be encoded for one or more products.

FIG. **13** depicts a sample tenant user interface of an embodiment of the invention providing order (request) confirmation details pursuant to a request by the tenant for one or more NFC tags to be encoded for one or more products.

FIG. **14** depicts a sample encoding and tracking interface of an embodiment of the invention depicting end user tap interactions with one or more encoded NFC tags for one or more products.

FIG. **15** depicts a sample user interface of an embodiment of a tracking module portion of the invention depicting one or more tap interactions by end users including precise geolocation(s) for each tap as displayed on a map.

FIG. **16** depicts a sample tenant user interface of an embodiment of the invention providing details of an end user tap interaction for an encoded tag affixed to a product.

FIG. **17** depicts a sample verification certificate issued in response to a tap interaction by an end user verifying the authenticity of the product to which an encoded tag has been affixed.

FIG. **18** depicts sample blocks of a blockchain recording an initial encoding transaction and subsequent tap interaction transactions.

FIG. **19** depicts a sample block of a blockchain wherein an initial encoding transaction is recorded in the first block.

FIG. **20** depicts a sample of code defining sample tap-transaction data compiled from a tap interaction that may be saved to a database portion in embodiments of the invention.

FIG. **21** depicts a sample subsequent block in a blockchain recording subsequent tap-transaction data from a tap interaction.

FIG. **22** depicts four (4) examples of tap-unique URLs generated by a suitable NFC tag that may be used in embodiments of the invention.

FIG. **23** depicts an example of an NFC tag with a tamper detection feature.

FIG. **24** depicts a perspective view of a brand electric guitar product with encoded tags embedded therein or affixed thereto.

DETAILED DESCRIPTION

Specific embodiments will now be described in detail with reference to the accompanying figures. Like elements in the various figures are denoted by like reference numerals for consistency. In the following detailed description of embodiments, numerous specific details are set forth in order to provide a more thorough understanding of the

invention. While described in conjunction with these embodiments, it will be understood that they are not intended to limit the disclosure to these embodiments. On the contrary, the disclosure is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the disclosure as defined by the appended claims. It will be apparent to one of ordinary skill in the art that the invention may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description.

The terminology used herein is for the purpose of describing exemplary embodiments only and is not intended to be limiting. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Furthermore, to the extent that the terms "including", "includes", "having", "has", "with", or variants thereof are used in either the detailed description and/or the claims, such terms are intended to be inclusive in a manner similar to the term "comprising".

As used herein, the term "tenant" means a manufacturer, producer, distributor, purveyor or seller of products, or any other party, including, for example, a certification organization, regulatory body, or governmental agency or entity, seeking to use the methods, process and systems of the present invention to track, verify, certify, or authenticate a product or any other tangible item.

As used herein, the term "product" means any tangible or intangible good, item or service and that is intended for delivery to a customer or end user, including, but not limited to, any commodity, agricultural product, cargo, ware, or shipment whether offered for sale (without regard to a specific value amount or price) or offered for no cost (i.e., free), and further including any packaging, accessories, and the like, or any other item of any kind (tangible or intangible) that a user or party, including, for example, a certification organization, regulatory body, or governmental agency or entity, may desire to track, verify, certify, or authenticate for any reason whatsoever.

It is understood that a "set" may include one or more elements. It is also understood that a "subset" of the set may be a set of which all the elements are contained in the set. In other words, the subset may include fewer elements than the set or all the elements of the set (i.e., the subset may be the same as the set). It is further understood that a set, including a subset, may be saved, modified, added to, subtracted from, processed, analyzed, read, sorted, subject to recursive and repeated steps, used, structured, deleted, re-generated, and the like.

It is understood that a "subprocess" may include one or more steps. It is also understood that a "subprocess" of a process may comprise all the steps contained in the process. In other words, the subprocess may include fewer steps than the process or all the steps of the process (i.e., the subprocess may be the same as the process). It is further understood that a process, including a subprocess, may be modified, added to, subtracted from, sorted, reorganized, subject to recursive and repeated steps, used, structured, deleted, re-generated, and the like.

It is also understood that the term "embodiment" is meant to include one or more embodiments (singular and plural) and that the term "embodiments" is also meant to include only one embodiment (singular and plural).

As used herein, the term "data structure" means a set, including any and all subsets, of one or more data (including metadata) that may be dynamically generated or created at any time, wherein the data may be obtained from any number of sources, including, but not limited to, one or more databases, devices, servers, modules, software, metadata, and the like, and wherein the data structure may be stored, recorded (including in a database, a blockchain, and the like), transmitted, saved, modified, added to, subtracted from, processed, and/or changed, and wherein the data structure may be further identified, analyzed, read, sorted, subject to recursive and repeated steps, used, structured, deleted, re-generated, and the like.

As demonstrated in this disclosure, embodiments of the invention may generally be comprised of two phases or portions: (1) an encoding phase, wherein a one or more unique individual NFC tag(s) **10** to be used or associated with, or incorporated within, a one or more respective unique individual product(s) **8**, is/are encoded and encrypted for such use and then placed on, in, or within product(s) **8** for which encoded NFC tag(s) **10** was/were created, and (2) an tap interaction or phase, wherein encoded NFC tag(s) **10** placed on, in, or within product(s) **8** is/are tapped or otherwise interacted with by a proximity coupling device (PCD) reading device **14**, such as, for example (without limitation), an NFC enabled cell phone. Both phases or portions involve interactions with the blockchain to create an immutable transaction record for unique individual tag **10** and its corresponding, respective unique individual product **8**. These phases or portions of embodiments will become apparent when reviewing the disclosure in view of the drawings. That embodiments of the invention may generally comprise or be described or disclosed according to such phases or portions, which should not be construed to limit the nature or scope of the invention.

FIG. **1** is a schematic of a configuration **100** of an encoding portion or phase of an embodiment of the invention. The schematic of FIG. **1** is one embodiment of an encoding portion, which may be configured in numerous ways as would be appreciated by those skilled in the art. The claimed methods, processes and systems of the invention are not dependent on any particular configuration, and the configuration of FIG. **1** is presented merely as an example of implementing an encoding portion embodiment.

It is to be understood that when reference is made to unique individual tag **10** and its corresponding, respective unique individual product **8**, unless specifically noted otherwise, tag **10** means "one or more tag **10**" and product **8** means "one or more product **8**". In other words, use of the singular term "tag **10**" is intended to include the plural "tags **10**", with reference to the singular term "product **8**", which is also intended to include the plural "products **8**". It is to also be understood, unless expressly stated otherwise, that embodiments of the invention create a locked, mutual association between each unique individual tag **10** and its corresponding, respective unique individual product **8**, wherein all tap transactions involving tag **10** are to be construed—unless stated to the contrary—to concomitantly involve product **8**.

In FIG. **1**, tag **10** is an appropriately sized and technology implemented NFC tag to be encoded with specific data relative to a specific product produced by a manufacturer, seller, retailer, distributor or any other party desiring to affix an NFC tag **10** to product **8** for purposes of tracking, verifying, authenticating, conducting inventory control, providing product data, providing marketing information with respect to a one or more product(s) (collectively, all such parties referred to herein as "tenant(s)", as that termed is defined, above). As referred to in the NFC industry, NFC tag **10** is a proximity integrated circuit card or "PICC." A PICC

or smart card may be written to and/or read through contactless communication by a proximity card reader or "PCD," as described within that documentation, NFC Forum materials, and further within this disclosure.

Tag **10** communicates using near-field communication (NFC) protocols and is compatible with NFC Forum specifications and other relevant standards for contactless communication. In various embodiments, tag **10** may be an NFC card subject to the NFC standards and protocols of ISO/IEC 14443. In various embodiments, tag **10** may be an NFC card subject to the standards and protocols of ISO/IEC 7816, ISO 15693, ISO 18092 and/or ISO 29167, of which the contents of all are incorporated by reference in their entirety. They may be generally summarized as follows.

ISO 14443 defines the standard for proximity contactless smartcards, establishing the physical characteristics, radio frequency interface, and transmission protocols for data exchange at 13.56 MHz. It distinguishes between two communication types (A and B) and ensures reliable, short-range interactions between cards and readers, often used in identity and payment systems.

ISO 15693 addresses vicinity cards, which are designed for longer reading distances compared to proximity cards. It specifies protocols and command sets to facilitate contactless communication at similar frequencies but with extended range, supporting applications like inventory management and access control where a greater distance between tag and reader is beneficial.

ISO 18092 focuses on near field communication (NFC), providing guidelines for peer-to-peer communication between devices as well as between devices and tags. It builds on RFID principles to allow two-way, close-proximity interactions at 13.56 MHz, specifying data exchange formats, modulation techniques, and anti-collision methods to ensure seamless and secure communications.

ISO 29167 extends RFID standards by incorporating cryptographic methods to enhance security in RFID and NFC communications. It defines a framework of cryptographic protocols and cipher suites that help protect data integrity, authenticate devices and tags, and prevent unauthorized access, making the communication more robust against interception and tampering.

In various embodiments, tag **10** may be any commercially available NFC tag suitable for the methods, processes, and systems disclosed herein. Tags suitable for use in embodiments may incorporate cryptographic capabilities, such as generating unique interaction-specific data or authentication data upon each read-out by proximity coupling reading device **14**, e.g., an NFC-enabled mobile device or reader, and transmitting these securely for backend verification. Examples of suitable tags include those with AES-128 cryptographic features or other equivalent technologies. However, embodiments of the invention are not tag-specific and may accommodate a variety of NFC tags with similar functionalities.

In embodiments, as discussed further within the disclosure, tag **10** is encrypted at process **600** (and verified through sub-process **718**) using AES-128 cryptography (advanced encryption standard 128 using a fixed block size of 128 bits and a key size of 128, 192 or 256 bits, for example). It is specifically understood that the invention and the various encryption, decryption and verification steps and processes of embodiments thereof are not limited to AES-128 cryptography and that any suitable cryptography method may be used. See, for example, NFC standards and requirements.

Many suitable NFC tags for use in embodiments incorporate cryptographic operations to support dynamic, tap-unique authentication. These operations may include generating dynamic messages or secure unique data upon each interaction to ensure the authenticity, integrity, and confidentiality of the data exchanged. Such features provide robust solutions for product authentication, secure physical tag presence, and protected data exchange.

In embodiments, NFC tag **10** generates a secure tap-unique URL **93**, which may generally comprise, for example, a tap-unique cryptographic output **94**. Depending on the cryptographic methods used to encrypt various tag data **101** comprising tap-unique URL **93**, tap-unique cryptographic output **94** may comprise (1) message authentication codes ("MACs") (used for tags such as NXP 424 DNA, discussed below, to ensure data integrity and authenticity during transmission), (2) one-time passwords ("OTPs") (session-specific tokens used for interaction-level security in tags such as EM4425), and (3) digital signatures (cryptographic signatures generated using on-chip ECDSA for Edge TruST25 tags, ensuring compatibility with blockchain-backed systems). Continuing, tag data **101** of tap-unique URL **93** may further comprise one or more tap-interaction data or metadata **113**, such as, for example, a unique tag identifier **103**, a tap interaction counter data **105** (a counter indicating the number of tap interactions), or other dynamic data, such as, for example a tag tamper status data **109** (a tamper detection feature). The tap-interaction data **113** may be transmitted to a backend system for validation in a verification process (see, e.g., process **718**A within the disclosure), which verifies the data's authenticity and integrity based on cryptographic methods, including but not limited to digital signatures, message authentication codes, or one-time passwords. The validation or verification process may confirm the authenticity of tag **10**, and hence, product **8** to which it was affixed, detect potential tampering, and ensure the presence of the physical tag during the interaction. In embodiments, the tap-unique URL further comprises a host server portion and unique product ID **95**.

Tags **10** may also support secure data transmission protocols compliant with NFC Forum standards and ISO/IEC specifications, ensuring compatibility across various NFC-enabled devices. For example, tags **10** may encode tap-interaction specific data **113** in formats such as NFC Data Exchange Format (NDEF), which facilitates seamless interaction with NFC-enabled mobile devices without requiring dedicated applications. Dynamic or encrypted metadata encoded in tag **10** may include unique tag identifier **103**, an interaction counter generating tap counter data **105**, and optional tamper detection feature that generates tag tamper status data **109**.

In some embodiments, tag **10** may comprise a tamper detection feature that generates a tamper status data **109**. This functionality may involve a detection mechanism that monitors the integrity of the tag's physical state and triggers a flag or status change upon tampering. The tamper status data **109** may be reflected in dynamic messages generated by the tag or included in encrypted metadata transmitted during interactions.

Tags **10** supporting file-based memory structures may allocate memory for dynamic and static content, allowing flexibility in encoding secure messages, metadata, or user-defined information. Encrypted communication modes can further protect sensitive applications, ensuring compliance with modern data protection regulations.

In embodiments, tag **10** may utilize configurable features to support encrypted or plaintext communication of its dynamic data. These features may include secure randomization of unique tag identifiers or dynamic updates to

interaction counters, ensuring compliance with user privacy standards and preventing replay attacks.

For tags **10** incorporating tamper detection, tamper status data **109** may include both permanent and current states, enabling real-time detection and historical tracking of tampering events. Upon a tamper event, the status may be irreversibly stored in non-volatile memory (NVM) and transmitted during subsequent interactions to alert users or backend systems of a potential compromise.

Embodiments of the invention accommodate various NFC tags with tamper detection features, dynamic messaging capabilities, and cryptographic support, ensuring flexibility in implementing the disclosed systems and processes.

An example of a suitable tag **10** is the "NT4H2421Gx" NFC tag by NXP B.V. ("NXP") (see www.nxp.com). The NT4H2421Gx NFC tag is sold under the tradename "NTAG 424 DNA" (the "424 DNA Tag"). Specific technical data concerning the 424 DNA Tag may be found on the NXP website and in the NXP product data sheet document titled "NT4H2421Gx" dated Jan. 31, 2019 (available at https://www.nxp.com/docs/en/data-sheet/NT4H2421Gx.pdf) and the application note document titled "AN12196" dated Aug. 19, 2024 (available at https://www.nxp.com/docs/en/application-note/AN12196.pdf), the contents of which both documents are incorporated herein by reference in their entirety. For clarity, the 424 DNA Tag is discussed on the basis that it is an NFC tag suitable for implementing embodiments of the invention and such embodiments of the invention are not tag specific. Other suitable NFC tags are commercially available.

The 424 DNA Tag utilizes an MAC cryptographic process resulting in an MAC cryptographic output in tap-unique URL **93**; an example configuration with placeholders may be as follows:

---

https://choose.url.com/ntag424?e=00000000000000000000000000000000&c=0000000000000000

The tag data **101** of tap-unique URL **93** generated by the 424 DNA Tag comprises unique tag identifier **103**, which may be configured to randomly generate upon a tap interaction and an interaction counter data **105**.

An example of another suitable NFC tag for embodiments of the invention is the "NT4H2421Tx" NFC tag, also by NXP and sold under the tradename "NTAG 424 DNA TT." The NXP NT4H2421Tx tag differs from the NXP NT4H2421Tx tag in that it features a smart status awareness, detecting the status of a tamper loop. Users can instantly detect the once-opened status, by just reading the tag with an NFC enabled device, such as PCD reading device **14**. The chip irrevocably stores this event and mirrors it into the NDEF message during startup. Specific product and technical data concerning the tamper protection feature of this 424 Tag may be found on the NXP website and in the NXP product data sheet document titled "NT4H2421Tx" dated Jan. 31, 2019 (available at https://www.nxp.com/docs/en/data-sheet/NT4H2421Tx.pdf) ("NT4H2421Tx Document"). The NT4H2421Tx tag comprises a tamper detection wire as illustrated in FIG. **13** in the NT4H2421Tx Document. See Example 5, set forth at FIG. **23**. When the tag tamper protection feature of the NT4H2421Tx tag is enabled, it is possible to mirror tag tamper status data **109** in the tag data **101** portion of tap-unique URL **93**. In embodiments, tag **10** comprises a tag tamper detection feature in the same or similar form as that comprising the NT4H2421Tx tag which generates tag tamper status data **109**.

Continuing with FIG. **1**, encoding of tag **10** is accomplished by a PCD encoding device **20**, in this example, an encoding terminal, functionally connected to NFC encoding module **30** operating on local encoding device **40**, such as a laptop, desktop computer or other similar computer device, including, for example, a thin layer client device (e.g., Raspberry Pi®). PCD encoding device **20** is functionally connected to the local encoding device **40** via wired or wireless technologies. In an embodiment, for example, PCD encoding device **20** is functionally connected to encoding device **40** through a standard USB connection. By accessing encoding module **30** operating on local encoding device **40**, a user may execute various commands and functions that power, communicate with, and encode various data to tag **10** from and through PCD encoding device **20**. For example, with respect to the 424 Tag, various features and functions of that tag may be configured, implemented, encoded, instructed and the like according to established NFC communications protocols and data exchange formats and as per NXP documentation for that tag. PCD encoding device **20** and NFC tag **10** communicate through established NFC communications protocols and data exchange formats based on existing radio frequency identification (RFID) standards, such as, but not limited to, ISO/IEC 14443 and FeliCa. The standards also include ISO/IEC 18092 and those defined by the NFC Forum. (NFC communicating in one or both directions uses a frequency of 13.56 MHz in the globally available unlicensed radio frequency ISM band, compliant with the ISO/IEC 18000-3 air interface standard at data rates ranging from 106 to 848 kbit/s.)

In an embodiment, PCD encoding device **20** and local encoding device **40**, may be a single device that performs all encoding operations, with NFC encoding module **30** operating on that single device. An example of such an embodiment includes, but is not limited to, an NFC enabled cell phone, wherein the cell phone serves as the PCD encoding device **20** (by tapping the NFC tag **10** to be encoded) and further serving as the local encoding device **40** operating encoding module **30** to provide an interface so as to allow a user to selectively determine the encoding parameters, functionality of NFC tag **10**, encryption means, placeholder URL (for tap-unique URL **93**), and any other configurations, functions and data selection of various embodiments.

NFC encoding module **30** may comprise an executable software, application or program functionally operating on NFC encoding device **40** that serves as an operable interface between API module **220** and PCD encoding device **20**. Encoding module **30** provides the appropriate functionality to allow a user of the system to interact with tag **10** through PCD encoding device **20**, configure and establish settings of tag **10** (in accordance with the manufacturer specifications for NFC tag **10** and applicable NFC standards and protocols), encode tag **10** with applicable data, for example, in accordance with embodiments disclosed herein, and encrypt tag **10** according to manufacturer specifications and applicable NFC and AES protocols, as discussed in the disclosure. Encoding module **30** may obtain and/or generate data for use with tag **10** from any number of sources, local or remote, and further including, but not limited to, API module **220** as disclosed herein. Encoding module **30** may be proprietary or obtained from third party sources, such as, for example, a manufacturer of NFC tag **10**.

Continuing with FIG. **1**, in embodiments, encoding module **30** operating on local encoding device **40**, may be functionally connected via a wired or wireless network to API module **220** running on an at least one sever **202**, which may be a local server, a dedicated server located remotely

from local encoding device **40**, or one or more cloud-based servers, or any combination thereof. In an embodiment, as per FIG. **1**, API module **220** is functionally connected to one or more database module(s) **302**, such as, for example, an SQL database, running on a server (local, remote or cloud-based). In embodiments, database module **302** and/or API module **220** may be configured to operate on the same or separate servers or on virtual machines on the same server. In yet other embodiments, database module **302** and/or API module **220** may be configured to operate on local encoding device **40**. In embodiments, database module **302**, API command module **220**, local encoding module **30**, or any combination thereof, may be configured to operate on the same device, which may comprise, in embodiments, PCD encoding device **20** and/or local encoding device **40**, configured separately or as a single device.

In embodiments, API (application program interface) module **220** is a software, application or program operating on a computer or computing device, such as a server, that functions as the central operational control point and communication bridge, interfacing with NFC encoding components (e.g., NFC encoding module **30**, NFC encoding device **40**, and/or PCD encoding device **20**), database module **302**, and blockchain module **322**. API module **220** may be built using Java, and employing a structured SQL database, ensures seamless management, processing, and validation of data across the authentication lifecycle as disclosed in various embodiments herein. API module **220** may operate on a server environment (local, dedicated, or cloud-based) and exposes standardized endpoints to facilitate secure communication between system modules.

In embodiments, primary functions of API module **220** may include, but are not necessarily limited to, the following:

Tag Encoding and Data Management. In embodiments, and as discussed further in the disclosure, API module **220** receives tag order requests **62** from tenants via tenant interface module **260**, generates unique product IDs **95** for products **8** to be used or associated with specific NFC tags **10** for each product, and generates data structures **89** for various steps, processes and operations of embodiments, such as, for example, data structures **89** for a transaction request **83** (e.g., a JSON RPC request) or into an SQL-compatible format for use with database module **302**. In embodiments, API module **220** transmits data structures **89** to the NFC encoding module **30** for tag **10** encryption and encoding processes while maintaining a secure record in database module **302**.

Blockchain Integration. In embodiments, acting as the bridge between the SQL database module **302** and blockchain module **322**, API module **220** commits immutable data structures **89**, such as data structures **89** comprising unique product IDs **95** and related product and tenant meta data in connection with the encoding process of NFC tag **10**, as well as unique tap-interaction data **113** generated from a tap interaction with a specific tag **10**, to blockchain module **322**. In embodiments, API module **220** ensures traceability and provides consensus-backed validation via blockchain module **322** to users of the system and methods of the invention, including tenants and consumer end users.

Verification and Authentication. In embodiments, and discussed further within, for tap interactions, API module **220** processes incoming HTTP GET requests initiated via the tag respective tap-unique URLs **93**. In embodiments, and as discussed further within this disclosure, using a tenant-specific encryption key **99** (retrieved securely from a Key Management Service or KMS **342**), API module **220** decrypts, validates, and verifies the authenticity of NFC tag **10** (see process **700** in FIGS. **7**A-**7**C). In embodiments, the validation and verification steps may include re-encryption or cryptographic processing of portions of tap-unique URL **93** (e.g., authentication data or metadata within the tap-unique URL **93**) to match corresponding cryptographic outputs (e.g., hashes, signatures, or other authentication data) and confirm data integrity (see process **700** in FIGS. **7**A-**7**C).

In embodiments, technical implementation of API module **220** may comprise, but are not necessarily limited to, the following:

Languages/Framework. In embodiments, API module **220** may be built using Spring Boot, a Java-based framework optimized for creating robust, scalable RESTful services. In embodiments, API module **220** may be built using any number of languages, such as, for example, Python frameworks (e.g., Django, a high-level Python web framework that encourages rapid development and clean, pragmatic design; Flask, a lightweight WSGI web application framework that's easy to get started with and highly flexible); Node.js frameworks (e.g., Express.js, a minimal and flexible Node.js web application framework that provides a robust set of features for web and mobile applications; NestJS, a progressive Node.js framework for building efficient, reliable, and scalable server-side applications using TypeScript); and other frameworks (e.g., Ruby on Rails, a server-side web application framework written in Ruby, emphasizing convention over configuration; .NET Core, a cross-platform, high-performance framework for building modern, cloud-based, and internet-connected applications).

Data Management. In embodiments, data interactions of API module **220** leverage SQL databases (comprising, for example, database module **302**), ensuring efficient storage, retrieval, and indexing of tag-related data structures **89**.

Security. In embodiments, API module **220** integrates with key management service (KMS) **342** for encryption key **99** generation and retrieval. API module **220** may also employ AES-128 encryption for secure data handling.

Blockchain Interaction. In embodiments, API module **220** communicates with blockchain module **322**, for example, a Hyperledger blockchain, via transaction requests **83** (e.g., via JSON-RPC requests), ensuring efficient recording and validation of tag data structures **89** and tap-interaction data **113**, including tag verification results **111**, on the immutable ledger of blockchain module **322**, all of which is discussed in greater detail with respect to process **700** at FIGS. **7**A-**7**C.

By coordinating the flow of data and operations between tenants, local encoding modules, databases, and blockchain components, in embodiments, API module **220** ensures the systems and process of embodiments function as a cohesive, secure, and tamper-proof solution for product authentication and verification.

Continuing with FIG. **1**, API module **220** is further functionally connected, via a wired or wireless network, to blockchain module **322** running on a server (local, remote or cloud-based). Alternatively, in an embodiment, API command module **220** and blockchain module **322** may be configured to operate on the same or separate servers or on virtual machines on the same server, or any combination of the foregoing.

As used herein, blockchain module **322** refers to a blockchain, an immutable ledger for recording transactions. In embodiments, API module **220** integrates and consolidates data and information from various sources as more specifically provided herein. In some embodiments, at least some of the data and information from the various sources may be

stored or recorded in blockchain module **322**, which may be maintained by a distributed network of nodes. In some embodiments, a consensus protocol may be used by the nodes to determine whether to allow transactions to be performed and group the transactions into blocks that are added to the blockchain comprising blockchain module **322**.

Regarding blockchains, in general, there are different kinds, such as permissionless and permissioned. In a permissionless blockchain, any entity may participate without an identity. In a permissioned blockchain, each entity that participates in the blockchain is identified and known. Examples of permissioned blockchains include Hyperledger Fabric, Hyperledger Sawtooth, IBM Blockchain Platform, and Quorum. Permissioned blockchains enforce strict identity verification, allowing participating nodes to view only the transactions appropriate to their access level. Programmable logic may be implemented as rules or smart contracts that are executed by the blockchain platform.

In embodiments, blockchain module **322** may comprise or implement one of the aforementioned platforms, such as Hyperledger Fabric, Hyperledger Sawtooth, Ethereum, IBM Blockchain Platform, or Quorum, depending on the deployment requirements. Each of these platforms provides a verifiable trace of proof that the content stored on the blockchain is associated with unique individual tag **10** and its respective unique individual product **8**. In embodiments, data such as, for example, unique product ID **95** and/or unique tag identifier **103** (among other data), may be recorded to blockchain module **322**, creating a secure chain of record and providing verification of that information.

In embodiments, when blockchain module **322** comprises Hyperledger Fabric, it operates as a modular distributed ledger solution. Hyperledger Fabric is a permissioned blockchain infrastructure providing a modular architecture with a delineation of roles between the nodes in the infrastructure, execution of Smart Contracts (called "chaincode" in Fabric), and configurable consensus and membership services. A Fabric network comprises (1) Peer nodes, which execute chaincode, access ledger data, endorse transactions, and interface with applications; (2) Orderer nodes, which ensure the consistency of the blockchain and deliver the endorsed transactions to the peers of the network; and (3) Membership Service Providers (MSPs), each generally implemented as a Certificate Authority, managing X.509 certificates to authenticate member identity and roles. Hyperledger Fabric supports different consensus algorithms, with Practical Byzantine Fault Tolerance (PBFT) being one commonly used.

Alternatively, in embodiments, blockchain module **322** may comprise Hyperledger Sawtooth, a highly modular platform designed for non-cryptocurrency applications. Sawtooth uses a Proof of Elapsed Time (PoET) consensus mechanism, providing scalability and low energy consumption. It allows smart contracts to be written in various programming languages, making it suitable for supply chain applications and asset tracking.

For applications requiring a public or hybrid blockchain, blockchain module **322** may implement Ethereum. Ethereum provides a decentralized platform for executing smart contracts on its blockchain using the Ethereum Virtual Machine (EVM). Smart contracts on Ethereum enable automated recording of tag interactions, ensuring transparency and verifiability.

In another embodiment, blockchain module **322** may integrate with the IBM Blockchain Platform, an enterprise-grade implementation of Hyperledger Fabric. This platform provides tools for building, operating, and governing permissioned blockchain networks with enhanced security, scalability, and user management features tailored for enterprise use cases.

Finally, in embodiments, blockchain module **322** may utilize Quorum, a permissioned variant of Ethereum. Quorum provides enterprise-focused features such as private transactions, enhanced data privacy, and faster transaction processing, making it ideal for scenarios requiring selective data sharing within a consortium.

Each of these blockchain platforms offers unique advantages, allowing blockchain module **322** to be tailored to the specific requirements of the application, whether it prioritizes scalability, privacy, consensus mechanisms, or integration with existing systems.

In embodiments, API module **220** is comprised with various administrative permissions, including permissions regarding transactions with blockchain module **322**. API module **220** functions as the central authority, exclusively authorized to initiate and manage transactions on blockchain module **322**. By centralizing transaction authority within API module **220**, embodiments of the invention establish a secure and controlled environment that mitigates the risk of unauthorized access and preserves the integrity of data and transactions recorded on blockchain module **322**.

In embodiments, API module **220** employs strong authentication mechanisms generally known by those skilled in the art, such as mutual transport layer security ("TLS"), to verify identity and to ensure that only authorized actions are permitted. This approach guarantees that administrative tasks—including configuring network parameters, managing peer nodes, and overseeing overall blockchain operations—are handled with the highest level of security and precision.

Continuing with blockchain module **322**, the blockchain may be a "fee-less" blockchain. Fee-less blockchains represent a unique category of blockchain technology designed to eliminate the transactional fees typically associated with traditional blockchain platforms. Unlike platforms such as Ethereum or Bitcoin, which charge fees (often referred to as "gas") for validating and processing transactions, fee-less blockchains operate without such costs, making them particularly appealing for use cases requiring high transaction throughput, microtransactions, or cost-sensitive applications.

Fee-less blockchain implementations achieve this functionality by employing alternative consensus mechanisms and network economics. For instance, certain platforms utilize Delegated Proof of Stake (DPOS) or Proof of Authority (PoA) consensus mechanisms, where a limited and pre-approved set of validators process transactions. These validators are often incentivized through alternative means, such as staking rewards or organizational funding, rather than user-imposed transaction fees.

In embodiments, blockchain module **322** may utilize fee-less blockchain platforms such as Hyperledger Fabric, IOTA, or Nano to support applications requiring frictionless interactions. Hyperledger Fabric, for instance, is inherently fee-less because it is designed as a permissioned blockchain infrastructure where all participants are pre-identified and operate under organizational governance. Instead of requiring transaction fees to incentivize or reward validators, Hyperledger Fabric relies on pre-established trust and shared goals among consortium members. This makes it particularly suitable for enterprise applications, where the cost of operating the network is shared among participants rather than imposed on individual transactions.

Hyperledger Fabric's modular architecture provides the flexibility to configure consensus mechanisms, such as Practical Byzantine Fault Tolerance (PBFT), without relying on fees to drive network participation. By centralizing control of network access and transaction validation through Membership Service Providers (MSPs), organizations leveraging Hyperledger Fabric can achieve fee-less transaction processing while maintaining robust security, scalability, and privacy.

Additionally, platforms like IOTA and Nano employ innovative designs to achieve fee-less transactions. IOTA uses a Directed Acyclic Graph (DAG) structure, known as the Tangle, where users validate two previous transactions to add their own to the ledger, eliminating the need for fees. Nano utilizes a block lattice architecture, where each account has its own blockchain, and transactions are processed through lightweight consensus mechanisms such as Open Representative Voting (ORV).

In embodiments, blockchain module **322** may also incorporate Decentralized Identifiers (DIDs) to enhance product authentication and user privacy. DIDs are a globally unique and resolvable identifier system designed for secure, verifiable, and privacy-preserving interactions. By linking DIDs to unique product IDs or tag identifiers stored in the blockchain, the system ensures that products can be authenticated without exposing sensitive user or organizational data. This approach allows for decentralized and trustless verification while maintaining data privacy and control.

The use of DIDs in blockchain module **322** also facilitates advanced privacy-preserving features, such as selective disclosure of product or authentication details. For instance, a user may verify the authenticity of a product without revealing personal data, ensuring compliance with privacy regulations like GDPR or CCPA. DIDs also enable cross-platform compatibility, allowing seamless integration of blockchain module **322** with external systems for supply chain tracking or customer engagement.

By integrating fee-less blockchains, including Hyperledger Fabric and other innovative technologies like DIDs, embodiments of blockchain module **322** provide enhanced accessibility for users and organizations by removing financial barriers to entry. Applications such as product authentication, supply chain tracking, or customer engagement can benefit from the seamless and cost-efficient nature of fee-less transactions, ensuring scalability while maintaining a secure and transparent ledger.

In some embodiments, blockchain module **322** may utilize a hybrid approach, combining fee-less blockchains like Hyperledger Fabric with traditional permissionless blockchains for specific use cases. This configuration allows applications to take advantage of the cost efficiency of fee-less systems for high-volume transactions while leveraging the public auditability and decentralized nature of permissionless blockchains for broader transparency.

Fee-less blockchains also align with sustainability goals by reducing the energy consumption typically associated with transaction validation on proof-of-work networks. This makes them an environmentally friendly choice for organizations prioritizing sustainability in their operations.

Continuing with FIG. **1**, in embodiments, local tenant device **60** is a functional computing device, such as, for example, a laptop or desktop, accessible by a tenant to functionally connect, via a wired or wireless network, to tenant interface module **260** operating on server **202**. Referring to FIG. **1**, using the systems, methods and processes of various embodiments of the invention, a tenant may use a web browser operating on local tenant device **60** to access tenant interface module **260** which may generally comprise a website. In the embodiment of system **100**, after accessing interface module **260**, which may be provided as a SaaS based service, a tenant would enter appropriate account information, such as login information generally comprising a username and password, or any other required information, wherein said information is transmitted to authentication module **270**. In embodiments, interface module **260** and tenant login module **270** are functionally interoperable, with interface module **260** comprising the "front end" and authentication module **270** comprising the "back end" of the tenant access system and process to allow a tenant to transmit data and information to API module **220** for further processing and transmittal in accordance with embodiments. Mobile tenant device **68** provides an alternative means by which a tenant may access interface module **260**. Specifically, mobile tenant device **68** may comprise a wireless device, such as a cell phone, that is functionally connected to tenant interface module **260** operating on server **202**.

Encoding NFC tag **10** with the embodiment of system **100** of FIG. **1** comprises, among other things, implementation of various NFC communications and technology. Near-field communication or NFC is a set of communication protocols that enables communication between two electronic devices over a distance of 10 centimeters or less. Regarding the present invention, in embodiments, tag **10** is encoded with specific, unique and immutable data associated with an exact product **8** that may be read by a second proximity coupling device or PCD reading device **14**, such as a cell or mobile phone, to verify or authenticate product **8** associated with tag **10** (among many other potential uses). Like other proximity card technologies, NFC is based on inductive coupling between two electromagnetic coils present in an NFC-enabled device such as a smartphone. NFC communicating in one or both directions uses a frequency of 13.56 MHz in the globally available unlicensed radio frequency ISM band, compliant with the ISO/IEC 18000-3 air interface standard at data rates ranging from 106 to 848 kbit/s. NFC communications involve an initiator and a target; the initiator actively generates an RF field that can power a passive target. For example, concerning embodiments of the present invention, the initiator may be a cell or mobile phone, i.e., PCD reading device **14**. The target is NFC tag **10**. This enables NFC targets to take very simple form factors such as unpowered tags, stickers, key fobs, or cards.

NFC tags contain data and are typically read-only but may be writable. They may be custom encoded by their manufacturers or use NFC Forum specifications. The tags may securely store personal data such as debit and credit card information, loyalty program data, PINs and networking contacts, among other information. In this case, as demonstrated by various embodiments described herein, NFC tag **10** is encoded and encrypted with data associated with or connected to other data concerning product **8**, a specific individual item. As described above, the 424 DNA Tag by NXP is an example of a suitable NFC tag **10**.

Although the components of system **100** are depicted as being directly communicatively coupled to one another, this may not necessarily be the case. For example, one or more of the components of system **100** may be communicatively coupled via a distributed computing system, a cloud computing system, or a networked computer system communicating via the Internet.

Although embodiments of an encoding portion of the invention are illustrated in system **100**, it should be appreciated that this system may represent many computer/networking systems, arranged in a central or distributed fash-

ion. For example, such systems may be organized as a central cloud and/or may be distributed geographically or logically to edges of a system such as a content delivery network or other arrangement. It is understood that virtually any number of intermediary networking devices, such as switches, routers, servers, etc., may be used to facilitate communication.

FIG. **2** is a schematic depicting a tap interaction between PCD reading device **14**, in this case a cell phone, and an encoded NFC tag **10**. As demonstrated in FIG. **2**, PCD reading device **14** provides the requisite electromagnetic (radio frequency) energy to "power up" tag **10**. In embodiments, tag **10** comprises a general substrate material **11**, such as paper, plastic, composites or any combination thereof, an integrated circuit (microchip) **13** to which data may be stored (encoded), encrypted and read, and to which various executable software instructions may be embedded, and a thin wire antenna **15**, typically a copper coil, for capturing the electromagnetic radiation transmitted from PCD reading device **14**. In embodiments, tag **10** may comprise a tamper protection element, such as, for example, an impedance loop that signals a tampered state if broken. In this regard, see the above discussion of example tag NT4H2421Tx and FIG. **23**.

While not intended to limit the scope of any embodiment of the invention, by way of background, and with reference to FIG. **2**, a tap interaction between PCD reading device **14** (and/or PCD encoding device **20** since PCD reading device **14** and PCD encoding device **20** may be the same, single device) and tag **10** generally involves the following steps:

Proximity Activation: When PCD reading device **14** comes within a close range (typically 10 centimeters) of tag **10**, it initiates the communication process.

Electromagnetic Induction: PCD reading device **14** emits an electromagnetic signal that is captured by copper coil antenna **15** in NFC tag **10**. This signal generates a small electrical current in the coil.

Powering the Microchip **13**: The generated electric current powers integrated circuit microchip **13** in tag **10**. Integrated circuit microchip **13** stores data, including executable program functions. In embodiments, a suitable NFC tag **10**, for example, the 424 Tag discussed above, features its own proprietary integrated circuit microchip.

Data Transmission: Integrated circuit microchip **13** uses this power to transmit its stored data, and any data processed by tag **10** according to its internal coding and functionality back to PCD reading device **14** via inductive coupling.

Data Processing: PCD reading device **14** receives the data transmitted by tag **10** and may then process it according to the specific applications discussed further within this application.

While discussed in the context of PCD reading device **14**, the above steps generally apply to any applicable NFC PCD device, including, for example, PCD encoding device **20**.

FIG. **3** is a schematic depicting an alternative configuration of an encoding portion of an embodiment of the invention. In the encoding portion embodiment of FIG. **3**, API module **220**, database module **302** and blockchain module **322** are all operating on the same functional server **202** or on one or more virtual machines all running on the same functional server in cloud **102**. Those skilled in the art would readily appreciate that the various modules comprising system **100** of FIG. **1** and the system of FIG. **3** may be configured in numerous different ways without departing from the scope of the invention. The various systems depicted in the disclosure, particularly system **100** of FIG. **1**, are illustrative embodiments that demonstrate the invention and various additional features of those systems and should not be construed as limiting configurations.

FIGS. **6**A-**6**C depict process **600**, an encoding embodiment portion of the invention. Process **600** presents an embodiment process by which unique individual tag **10** may be encoded and encrypted according to an embodiment of the invention and with reference to system **100** of FIG. **1** for use with corresponding unique individual product **8**. The various steps comprising process **600** are addressed below and comprise numerous features and elements that may be combined, amended, re-organized or deleted without departing from the scope of the claimed invention.

Step **602**. At Step **602**, in an embodiment, a remote tenant user of system **100** desiring to encode at least one unique individual tag **10** for at least one unique individual product **8**, submits tag order request **62** to a provider of encoded and encrypted tags **10** for use with products for verification thereof. Tag order request **62** may be submitted by the tenant user through tenant user interface module **260** on server **202**. The tenant user may first access tenant user interface module **260** through a web client (web browser) running on tenant's local computing device **60**, which may comprise a computer, laptop, or any other device functionally connected to the Internet and capable of accessing tenant user interface module **260**. Alternatively, the tenant may access tenant user interface module **260** through mobile tenant device **68**. In an embodiment, tenant user interface module **260** may comprise a web site running on server **202** and accessible via the Internet. Upon tenant accessing tenant user interface module **260**, the tenant may login into tenant's account by means of a username and password or any other means known in the art for accessing a website or SaaS account on the Internet. If the tenant does not have an account at the time of seeking to submit tag order request **62**, the tenant may create an account at that time.

Step **604**. In embodiments, at Step **604**, once the tenant user logs into its account, which is verified on backend tenant login/authentication module **270**, tenant's tag order request **62** is submitted by tenant user interface module **260** to API module **220**.

Step **606**. In an embodiment, upon receiving tag order request **62**, API module **220** saves tag order request **62** to database module **302**. Tag order request **62** may comprise any number of features and elements desired by the tenant (see FIG. **9**, discussed below). Continuing with Step **606**, API module **220** transmits tag order request **62** to NFC encoding module **30**, running on local device **40**, for processing.

Step **608**. In embodiments, at Step **608**, upon receiving tag order request **62** from API module **220**, NFC encoding module **30** sends a data structure request **85** to API module **220** for purposes of creating one or more sets of data associated with, concerning, directed to and/or connecting or linking unique individual tag **10** with unique individual product **8**. In an embodiment, data structure request **85** may comprise a product identification (such as unique product ID **95** for each unique individual product **8**), a tenant identification (such as a tenant name, identification number, account number, and/or any other indicia identifying the tenant), the total number of unique individual products **8** that the tenant desires to have respective, unique individual tags **10** encoded, the number of tags **10** sought to be encoded by tenant pursuant to tag order request **62** (based on the number of unique individual products **8** unless, in embodiments, tenant desires more than one tag **10** per product **8**), and an identification of tag **10** type (for example, the 424 Tag, or any other commercially available and suitable NFC tag **10**).

In embodiments, data structure request **85** may include any other desired data and is not limited by the foregoing.

Step **610**. In an embodiment, at Step **610**, after receiving data structure request **85**, API module **220** obtains tenant's encryption key ID **86** from database module **302** in order to obtain tenant's encryption key **99** for purposes of encrypting tag **10** after it has been encoded according to embodiments. In the embodiment of FIG. **1** and process **600** in FIGS. **6**A-**6**D, tenant's encryption key **99** is stored and maintained by key management service (KMS) **342**, an encryption key storage server. In the disclosed embodiment, tenant's encryption key **99** is not stored in database module **302**; only tenant's encryption key ID **86** is stored in database module **302**. However, those skilled in the art would appreciate that in embodiments, tenant's encryption key **99** may be stored in database module **302** or in any other suitable fashion to maintain the integrity of encryption key **99**. In an embodiment, tenant's encryption key ID **86** (or in alternative embodiments, encryption key **99**) may be stored in database module **302** in association with various data and data structures related to the tenant. Those skilled in the art would appreciate the various means and ways that databases, including, but not limited to, SQL databases, may be structured or configured to associate such data associated with a tenant and one or more tenant products **8**, including, where appropriate, tenant's encryption key ID **86** and/or (if applicable) tenant's encryption key **99**.

Step **612**. In an embodiment, at Step **612**, after obtaining tenant's encryption key ID **86**, from database module **302**, API module **220** sends encryption key request **87** to KMS **342** to obtain tenant's encryption key **99**. In an embodiment, encryption key request **87** comprises tenant's encryption key ID **86** in order to obtain the encryption key **99** belonging to the tenant. In embodiments, encryption key request **87** may comprise additional tenant data necessary for obtaining tenant's encryption key **99** from KMS **342**.

Step **614**. At Step **614**, in embodiments, upon receiving encryption key request **87**, KMS **342** verifies whether tenant's encryption key **99** is valid (e.g., whether it may have expired, etc.). If tenant's encryption key **99** is expired or not valid for other acceptable reasons based on permissions, KMS **342** generates a new encryption key **99** for tenant. Upon securing tenant's encryption key **99**, KMS **342** transmits encryption key **99**, whether an existing, valid encryption key **99** or a newly generated encryption key **99**, to API module **220**.

Step **616**. In embodiments, after obtaining tenant's encryption key **99**, API module **220** generates a data structure **89** for tag **10** and saves it to database module **302**. At Step **616**, in an embodiment, a separate data structure **89** is generated by API module **220** for each unique individual tag **10** to be encoded. Data structure **89** is dynamic and may be modified as necessary by API module **220** and/or the SQL database in database module **302** based on specific data associated with tag **10** as may be required according to various steps and process requirements in embodiments of the invention. In an embodiment, in instances where multiple tags **10** are to be encoded, API module **220** may generate multiple, separate data structures **89**, wherein each specific data structure **89** is uniquely associated for each individual tag **10** to be encoded.

Step **618**. Continuing with process **600**, in embodiments, at Step **618** database module **302** generates unique product ID **95** for each individual tag **10** and adds it to data structure **89** for the tag **10**. In an embodiment, unique product ID **95** serves as the primary identifier linking unique individual product **8** with its respective, unique individual tag **10**. In various drawings of the attached figures, unique product ID **95** may be referenced therein using a different term for purposes of implementing the illustrated embodiment. As is noted in the disclosure, regardless of how any such implementing embodiment may refer to unique product ID **95** (as illustrated in a drawing), it is to be understood that the referenced feature is intended to comprise unique product ID **95** as specifically discussed herein. Continuing, in embodiments, database module **302** may save unique product ID **95** to the database in association with one or more data comprising data structure **89**. In an embodiment, in instances where multiple specific tags **10** are to be encoded each for a specific product **8**, database module **302** generates multiple separate unique product IDs **95**, a specific unique product ID **95** for each tag **10** to be encoded for the respective product **8**.

Step **620**. In embodiments, at Step **620**, database module **302** transmits data structure **89** with unique product ID **95** for each tag **10** to be encoded to API module **220**. In an embodiment, in instances where multiple tags **10** are to be encoded (with each unique individual tag **10** being encoded for each unique individual product **8**), database module **302** transmits multiple separate unique data structures **89** (each with its own unique product ID **95**) for each respective tag **10** to API module **220**. The transmittal of more than one data structure **89** from database module **302** to API module **220** at Step **620**, as with all process steps in all embodiments of the invention as presented in the flowcharts, may be performed serially or in parallel. While the various steps in the flowcharts are presented and described sequentially, one of ordinary skill would also appreciate that some or all of the steps may be executed in different order(s) and some or all of the steps may be executed in parallel. In addition, encoding and encrypting multiple NFC tags **10** according to a single operation or as may be directed by a user may be referred to as a "batch encoding," which is discussed further within the disclosure.

It is to be understood that data structure **89** may be comprised of any number of various discrete data items concerning unique individual product **8** and its corresponding unique individual tag **10**. In embodiments, for example, various product identifying information or indicia may comprise data structure **89** concerning unique individual product **8**. Examples may include, for example (and are not limited to), such identifying product indicia as universal product codes or UPC codes, bar codes, quick response or QR codes (or any other type of two-dimensional matrix barcode), electronic product or electronic product codes (EPC codes), GS1 DataMatrix codes, GS1 DataBars, ITF-14 codes, Code 128, RFID tag data and/or European Article Number or EAN codes. It is to be further understood that any suitable, appropriate and applicable metadata associated with any of the foregoing, unique individual product **8** and/or its corresponding unique individual tag **10**, or the tenant may also comprise, in whole or in part, data structure **89**. Various embodiments of the invention allow for numerous options and possibilities of data that may comprise a specific data structure **89** for a unique individual product **8**. Importantly, data structure **89** is directly associated with its unique individual product **8** and provides a link to tag **10** to be used with product **8** after tag **10** undergoes encoding.

Step **622**. At Step **622**, in an embodiment, API module **220** sends a transaction request **83** to blockchain module **322** to record data structure **89** to blockchain module **322**. In embodiments, a separate transaction request **83** is transmitted from API module **220** for each data structure **89** created for each unique individual product **8** and its respective

unique individual tag **10**. In alternative embodiments, transaction request **83** may comprise more than one data structure **89**. In each case, each individual unique data structure **89** comprising transaction request **83** corresponds to a unique specific tag **10** and its unique individual and corresponding product **8**. In embodiments, transaction request **83** may comprise a JSON-RPC request.

As used herein, the term 'blockchain module" **322** refers to any suitable blockchain or blockchain platform and/or any other suitable immutable ledger for recording transactions as is generally known in the art. In embodiments, API module **220** integrates and consolidates data and information from various sources and entities as more specifically provided in the disclosure. In some embodiments, at least some of the data and information from the various sources and entities may be stored or recorded on the blockchain. The blockchain may be maintained by a distributed network of nodes. In some embodiments, a consensus protocol may be used by the nodes to determine whether to allow transactions to be performed and groups the transactions into blocks that are added to the blockchain.

Generally, a blockchain is a distributed ledger with growing lists of records (i.e., "blocks") that are securely linked together via cryptographic hashes. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree, where data nodes are represented by leaves). Since each block contains information about the previous block, they effectively form a "chain" with each additional block linking to the ones before it. Consequently, blockchain transactions are irreversible in that, once they are recorded, the data in any given block cannot be altered retroactively without altering all subsequent blocks.

Blockchains are typically managed by a peer-to-peer (P2P) computer network for use as a public distributed ledger, where nodes collectively adhere to a consensus algorithm protocol to add and validate new transaction blocks. Although blockchain records are not unalterable, since blockchain forks are possible, blockchains may be considered secure by design and exemplify a distributed computing system with high Byzantine fault tolerance.

There are different kinds of blockchains, such as permissionless and permissioned. In a permissionless blockchain, any entity may participate without an identity. In a permissioned blockchain, each entity that participates in the blockchain is identified and known. Examples of permissioned blockchains include Hyperledger Fabric, Hyperledger Sawtooth, IBM Blockchain Platform, and Quorum, while permissionless blockchains include public systems like Ethereum. Permissioned blockchains enforce strict identity verification, allowing participating nodes to view only the transactions appropriate to their access level. Programmable logic may be implemented as rules or smart contracts executed by the blockchain platform.

Permissioned blockchains such as Hyperledger Fabric, IBM Blockchain Platform, and Quorum provide a verifiable trace of proof that the content stored or recorded on the blockchain is associated with specific, unique individual tag **10** and its respective unique individual product **8**. In embodiments, data such as data structure **89** which comprises unique product ID **95** (among other possible data, such as unique tag identifier **103**) is recorded to blockchain module **322**, creating a secure chain of record and providing verification of that information.

Hyperledger Fabric is a modular distributed ledger solution providing a permissioned blockchain infrastructure. A Hyperledger Fabric network comprises the following components:

(1) Peer nodes, which execute chaincode (Smart Contracts), access ledger data, endorse transactions, and interface with applications;

(2) Orderer nodes, which ensure the consistency of the blockchain and deliver the endorsed transactions to the peers of the network; and

(3) Membership Service Providers (MSPs), generally implemented as Certificate Authorities managing X.509 certificates to authenticate member identities and roles.

Hyperledger Fabric supports configurable consensus and membership services, with Practical Byzantine Fault Tolerance (PBFT) being one of the most commonly used consensus algorithms. Its modular architecture allows for customization and flexibility in various enterprise use cases.

Hyperledger Sawtooth is another permissioned blockchain platform that may be used in embodiments. Sawtooth is optimized for non-cryptocurrency applications, providing features such as dynamic consensus mechanisms (e.g., Proof of Elapsed Time (PoET)) and support for smart contracts in multiple programming languages. Its scalability and efficiency make it suitable for supply chain and asset tracking applications.

IBM Blockchain Platform is an enterprise-grade implementation of Hyperledger Fabric. It offers advanced tools for building, operating, and governing blockchain networks, ensuring robust security and scalability. This platform is particularly well-suited for enterprises seeking seamless integration with existing systems.

Quorum, a permissioned variant of Ethereum, supports private transactions and enhanced data privacy. Quorum utilizes smart contracts to enable selective data sharing within a consortium, making it ideal for industries requiring confidentiality alongside blockchain transparency.

Ethereum, a permissionless blockchain, provides a decentralized platform for executing smart contracts using the Ethereum Virtual Machine (EVM). Smart contracts on Ethereum enable automated recording and verification of tag interactions, ensuring transparency and immutability on a public or hybrid ledger.

As used herein, the term "Hyperledger" may refer to Hyperledger Fabric specifically or more broadly to Hyperledger's suite of blockchain technologies, including Sawtooth. However, blockchain module **322** is not limited to Hyperledger and may implement other platforms such as Ethereum, IBM Blockchain Platform, or Quorum. These platforms are discussed for illustrative purposes, and embodiments of the invention are intended to comprise any suitable blockchain technology capable of fulfilling the described functions.

Continuing with Step **622**, in an embodiment, transaction request **83** comprises a JSON-RPC request **83** (JavaScript Object Notation-Remote Procedure Call), a remote procedure call (RPC) protocol encoded in JSON. It is similar to the XML-RPC protocol, defining only a few data types and commands. JSON-RPC allows for notifications (data sent to the server that does not require a response) and for multiple calls to be sent to the server which may be answered asynchronously. JSON-RPC works by sending a request to a server implementing this protocol. The client (in an embodiment, API Module **220**) is typically software intending to call a single method of a remote system. Multiple

input parameters can be passed to the remote method as an array or object, whereas the method itself can return multiple output data as well.

Hereinafter, the term "transaction request **83**" may be referred to as "JSON-RPC request **83**". It is to be understood that the JSON-RPC request protocol/format is an embodiment of transaction request **83** and that the use of the term "JSON-RPC request **83**" does not limit the term "transaction request **83**" specifically to the JSON-RPC request format and protocol. Other remote procedure calls, such as, for example, the XML-RPC protocol, may be suitable. Those skilled in the art would appreciate any suitable remote procedure call protocols and formats for embodiments of the invention. As such, while an embodiment of the invention as illustrated in Step **622** et seq. comprises JSON-RPC request **83**, it should be understood that any applicable remote procedure call request may be implemented for carrying out the step. Those skilled in the art would appreciate any such suitable requests, methods and protocols.

Step **624**. At Step **624**, in an embodiment, upon receiving transaction request **83**, blockchain module **322** records data structure **89** in an initial unique blockchain transaction and generates an initial unique blockchain transaction ID **97**, i.e., a block hash, for data structure **89**. Specifically, blockchain module **322** initiates the recording of data structure **89** by generating a unique blockchain transaction ID (hash) **97**. This transaction is then broadcast to the blockchain network, where it undergoes validation through the consensus mechanism employed by the network. Depending on the architecture of the blockchain module, validation may involve mechanisms such as endorsement policies, proof of elapsed time, or other consensus protocols.

Once the initial blockchain transaction is initiated, an asynchronous listener service—a dedicated process external to the blockchain network—monitors the transaction's status within blockchain module **322**. Upon successful validation and commitment to the ledger, the listener service receives a notification confirming the transaction. At this point, in embodiments, the listener service relays the verified initial blockchain transaction ID **97** and associated data from data structure **89** to database module **302** via API module **220**, ensuring the database accurately reflects the state recorded on the blockchain. This architecture ensures secure, immutable record-keeping while allowing external systems to persistently store verified data without compromising blockchain integrity.

As used herein, the term "initial unique blockchain transaction" or "initial blockchain transaction" refers to the first transaction recorded on blockchain module **322** wherein data structure **89** is recorded in the initial block. Similarly, the term "initial unique blockchain transaction" or "initial blockchain transaction" with respect to ID **97** refers to the first block hash (i.e., blockchain transaction ID **97**) generated for the initial unique blockchain transaction. With reference to the figures, in embodiments, an initial blockchain transaction ID may be referred to as **97-01**. In accordance with blockchain functionality, there is only one initial unique blockchain transaction and one initial blockchain transaction ID **97-01** for unique individual product **8** and its associated unique individual tag **10**.

Reference is now made to FIGS. **18** and **19**.

FIG. **18** shows an example of blockchain module **322**, in accordance with various embodiments. Blockchain module **322** may be implemented using various permissioned or permissionless blockchain platforms, such as Hyperledger Fabric, Hyperledger Sawtooth, IBM Blockchain Platform, Quorum, or Ethereum. In this example, blockchain module **322** comprises three blocks: **1800-01**, **1800-02**, and **1800-03**. Each block is cryptographically linked to the previous block, except block **1800-01**, which serves as the initial block in the chain and is not linked to any previous block. Each block **1800** includes a unique blockchain transaction ID (block hash) **97** for that block, determined using a suitable hash function. For example, block **1800-01** has block hash **97-01** "12pbj," block **1800-02** has block hash **97-02** "25dym," and block **1800-03** has block hash **97-03** "37kfw."

The blocks are cryptographically linked together by including a block header with the block hash (unique blockchain transaction ID **97**) of the previous block. For example, block **1800-02** includes block header **1804-02**, which includes the previous block hash **97-01** from block **1800-01** with the value "12pbj." Continuing with FIG. **18**, block **1800-03** includes block header **1804-03**, which includes the previous block hash **97-02** from block **1800-02** with a value "25dym." The examples of block hashes in FIGS. **18** and **19** are provided for illustrative purposes.

Transaction Structure. In embodiments, each block **1800** may include one or more transactions **1802**. For example, block **1800-01** comprises a single transaction **1802-01**; block **1800-02** comprises a single transaction **1802-02**; and block **1800-03** comprises a single transaction **1802-03**. In some embodiments, blocks **1800** may store multiple transactions **1802**. The scope of the invention is not limited to a single transaction per block. Transactions **1802** may be grouped and added to a block **1800** upon satisfying the consensus requirements of the blockchain module **322**. These requirements may vary depending on the underlying blockchain platform. For example:

Hyperledger Fabric uses endorsement policies and practical Byzantine Fault Tolerance (PBFT) for consensus.

Hyperledger Sawtooth employs proof of elapsed time (PoET) for scalable and energy-efficient transaction validation.

IBM Blockchain Platform leverages a customized implementation of Hyperledger Fabric for enterprise-grade blockchain services.

Quorum implements private transactions with support for enterprise-focused consensus mechanisms.

Ethereum, though permissionless by default, may be configured as a private or consortium blockchain, using proof-of-stake or proof-of-work for transaction validation.

Cryptographic Linking and Validation. As shown in FIG. **18**, blocks **1800** are cryptographically linked through their headers. Each transaction **1802** undergoes validation before being committed to the ledger. For example, a transaction may be verified by peer nodes in a Hyperledger Fabric network or through validator nodes in a Sawtooth network. Once validated, the transaction is added to the chain, ensuring an immutable record of all interactions associated with the unique individual tag **10** and its respective unique individual product **8**.

Continuing with FIG. **18**, in embodiments, each block **1800** includes one transaction (**1802**). For example, block **1800-01** comprises singe transaction **1802-01**; block **1800-02** comprises single transaction **1802-02**; and block **1800-03** comprises single transaction **1802-03**. In embodiments, however, blocks **1800** may comprise multiple transactions **1802** and the scope of the invention is not limited to a single transaction per block. In some embodiments, blocks **1800** storing multiple transactions **1802** may be added to blockchain module **322** after it is determined that the one or more rules and/or consensus between nodes of the Hyperledger Fabric are satisfied. In embodiments, transactions **1802** in a

given transaction request **83** may be grouped and added as a block **1800** to blockchain module **322**, or different transactions **1802** from different requests **83** may be grouped and added as a block **1800**.

Continuing with FIG. **18**, in embodiments, transaction **1802-01** is an initial unique blockchain transaction and block **1800-01** is an initial block, the first block comprising the chain. The blockchain transaction ID **97** for that transaction, "12pbj", is an initial unique blockchain transaction ID and designated **97-01**. In the initial unique blockchain transaction of FIG. **18**, data structure **89** is recorded in the initial block, as discussed below with regard to FIG. **19**. In FIG. **18**, subsequent unique blockchain transactions **1802-02** and **1802-03**, and their respective unique subsequent blockchain transaction IDs **97-02** and **97-03** (respectively, "25dym" and "37kfw") are discussed further within the disclosure. For simplicity, subsequent unique blockchain transactions **1802-02** and **1802-03** are referred to herein simply as "subsequent blockchain transactions" in view of and in relation to the initial unique blockchain transaction of FIG. **18**.

Referring to FIG. **19**, in an embodiment, an example of initial transaction **1802-01** is illustrated in greater detail. Initial transaction **1802-01** of FIG. **19** is viewed with respect to Step **624**, wherein, in an embodiment, upon receiving transaction request **83**, blockchain module **322** records data structure **89** and generates initial unique blockchain transaction ID **97-01**, i.e., a block hash, for the initial transaction recording data structure **89**. In the embodiment of FIG. **19**, initial blockchain transaction **1802-01** comprises the recordation of data structure **89** in block **1800-01** for unique individual tag **10** for unique individual product **8**. In an embodiment, as illustrated in FIG. **19**, data structure **89** recorded in transaction **1802-01** may comprise one or more of the following data: unique product ID **95**, unique tag identifier **101**, (if applicable), tag type (e.g., the 424 Tag), tenant ID, order ID, date created, last updated date, and/or tenant's encryption key ID **86**. In embodiments, multiple tag structures **89**, each for a specific unique individual tag **10** for unique individual product **8** may be recorded in transaction **1802-01** based on one or more transaction requests **83**. In the example of FIG. **19**, initial blockchain transaction ID **97-01** for transaction **1802-01** is "12pbj". In addition, in the example of FIG. **19**, block **1800-01** does not comprise a block header, as transaction **1802-01** is an initial transaction for tag **10** and represents the first recording of data (data structure **89**) associated with unique individual tag **10** and unique individual product **8**.

As noted above, data structure **89**—the subject of an initial blockchain transaction of embodiments as illustrated in FIG. **19**—is specifically not limited to the example data structure **89** illustrated therein. In embodiments, for example, various product identifying information or indicia may comprise data structure **89** concerning unique individual product **8** and/or unique individual tag **10** for product **8**. Examples may include, for example (and are not limited to), such identifying product indicia as universal product codes or UPC codes, bar codes, quick response or QR codes (or any other type of two-dimensional matrix barcode), electronic product or EPC codes, GS1 DataMatrix codes, GS1 DataBars, ITF-14 codes, Code 128, RFID tag data and/or European Article Number or EAN codes. It is to be further understood that any suitable, appropriate and applicable metadata associated with any of the foregoing, unique individual product **8** and/or its corresponding unique individual tag **10**, or the tenant may also comprise, in whole or in part, data structure **89** to be recording in initial blockchain transaction **1802-01**. The are numerous options and possibilities of data that may comprise a specific data structure **89** for a unique individual product **8**. Any of the foregoing examples of product-based data or metadata may comprise data structure **89**, the recording thereof in blockchain module **322** comprising initial blockchain transaction **1802-01** in initial block **1800-01**.

Step **626**. In accordance with the above, in an embodiment, at Step **626** (and with reference to FIGS. **18** and **19**) blockchain module **322** transmits unique initial blockchain transaction ID **97-01** for initial blockchain transaction **1802-01** recording data structure **89** to API module **220**. Recording of data structure **89** in initial blockchain transaction **1802-01** in blockchain module **322**, and the generation and transmittal of unique initial blockchain transaction ID **97-01** to API module **220**, results from and is in response to transaction request **83** made by API module **220** at Step **622**.

Step **628**. In an embodiment, at Step **628**, API module **220** receives unique initial blockchain transaction ID **97-01** from blockchain module **322** (generated by blockchain module **322** for recording data structure **89**) and records initial blockchain transaction ID **97-01** to database module **302**. In embodiments, initial blockchain transaction ID **97-01** saved to database module **302** is associated with data structure **89** generated for and recorded on blockchain module **322** at Step **624** for unique individual tag **10** and unique individual product **8** and any other data comprising database module **302** concerning tag **10** and product **8**.

Step **630**. As Step **630**, in embodiments, API module **220** transmits unique product ID **95** (for tag **10** and product **8**) and encryption key ID **86** to encoding module **30** for use in the encoding and encrypting of tag **10** for use with unique individual product **8**. In some embodiments, API module **220** may obtain tenant's encryption key **99** in similar fashion to that disclosed at Steps **610-616** and transmit encryption key **99** to encoding module **30** with unique product ID **95** (for tag **10** and product **8**). In yet other embodiments, at Step **630**, API module **220** may further transmit data structure **89** in the same form or with the same data items or parameters, in whole or in part, as recorded on blockchain module **322** at Step **624** (initial blockchain transaction **1802-01**) or an alternative data structure **89** concerning product **8** for encoding on tag **10** or for saving to encoding device **40** running encoding module **30**. In embodiments, other data associated with product **8**, as discussed herein, may be transmitted by API module **220** to encoding module for encoding on tag **10** or for saving to encoding device **40** running encoding module **30**.

Step **632**. In embodiments, at Step **632**, using tenant's encryption key ID **86**, encoding module **30** sends encryption key request **97** to KMS **342** to obtain tenant's encryption key **99**. In embodiments, Step **632** may be performed in substantial or similar fashion to that disclosed at Steps **610-616**.

Step **634**. At Step **634**, in an embodiment, upon obtaining tenant's encryption key **99**, encoding module **30** initializes communication with tag **10** through functionally connected PCD encoding device **20**. This may be referred to as "powering up" tag **10** by the functionally connected PCD encoding device **20**. In alternative embodiments, the encod-

ing steps of encoding process **600**, including the powering up of tag **10**, may be carried about by one or more alternative PCD devices, such as, for example, PCD reading device **14** (e.g., a cell phone). This step initiates the encoding process of tag **10** for use with unique individual product **8**. The protocols for communicating and encoding tag **10** are established according to industry and tag manufacturer specifications as previously disclosed.

Step **636**. In an embodiment, and if required, at Step **636** encoding module **30** modifies configuration settings of tag **10** to allow for encoding and encryption of tag **10**.

Step **638**. In embodiments, at Step **638**, encoding module **30** reads tag data **101** of tag **10**, as previously defined. Tag data **101** may include, for example, a unique tag identifier **103**, an interaction counter data **105**, and/or a tamper status data **109**. Depending on the specific tag type, such as NXP 424 DNA, EM4425, or Edge TruST25, tag data **101** may also include cryptographic elements or metadata relevant to the tag's configuration, such as message authentication codes (MACs), one-time passwords (OTPs), or digital signatures. These components are essential for generating and verifying tap-unique URLs **93**.

Step **640**. In embodiments, at Step **640**, using tenant-specific encryption key **99** retrieved securely from KMS **342**, encoding module **30** encrypts tag data **101** of tag **10**. Upon encrypting tag data **101**, encoding module **30** generates a tap-unique URL **93** that incorporates encrypted tag data **101** and one or more cryptographic outputs **107** based on the tag type. Examples of cryptographic outputs include:

Message Authentication Codes (MACs): Used for tags such as NXP 424 DNA to ensure data integrity and authenticity during transmission.

One-Time Passwords (OTPs): Session-specific tokens used for interaction-level security in tags such as EM4425.

Digital Signatures: Cryptographic signatures generated using on-chip ECDSA for Edge TruST25 tags, ensuring compatibility with blockchain-backed systems.

Additionally, tag data **101** may include elements such as interaction counter **105** and tamper status **109**, depending on the tag type and configuration. For instance, upon powering up tag **10** at Step **634**, a random unique identifier may be generated to replace the existing tag identifier **103**. In addition, in embodiments, interaction counter data **105** may increment by one with each tap, ensuring a sequential interaction record.

Step **642**. In embodiments, at Step **642**, encoding module **30** encodes tag **10** with initial tap-unique URL **93**. The URL includes encrypted or plain tag data **101**, one or more cryptographic outputs **107**, and a unique product identifier **95**. Additionally, the URL includes a host website portion operating on host web server **230** to direct web client **16** operating on a proximity coupling device (PCD) **14** for interaction verification and authentication, as further detailed in process **700**.

Example Tap-Unique URLs. By way of example, tap-unique URL **93** encoded on tag **10** may take the following forms.

MAC Example (NXP 424 DNA)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwmCYnxBpqqEKBqp37azFouZLBG
  ?picc=063792A3AC712E6C7DA789D98BF9CA43&cmac=BEB842FD38CBD9B8
```

Wherein, "picc" comprises encrypted tag data **101** including the unique identifier and interaction counter, and "cmac" comprises cryptographic output **107**, i.e., the message authentication code (MAC) ensuring data authenticity and preventing replay attacks.

OTP Example (EM4425)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwmCYnxBpqqEKBqp37azFouZLBG
?uid=AAAAAAAAAAA&token=AAAA&f=A&sig=AAAAAAAAAAAAAAAAAAAAAA
```

Wherein, "uid" comprises a unique identifier **103** for the tag, "token" comprises a one-time password providing session-specific security, and "sig" comprises cryptographic output **107**.

Digital Signature Example (Edge TruST25)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwmCYnxBpqqEKBqp37azFouZLBG
  ?uid=063792A3AC712E6C7DA789D98BF9CA43&counter=56789&tamper=T&sig=ABC
    DEFGHIJKLMNopqrstuvwxyz012345
```

Wherein, "uid" comprises a unique identifier for the tag **103**, "counter" comprises interaction counter **105**, incremented to ensure sequential validation, "tamper" comprises a tamper status flag **109** indicating physical compromise (T for tampered), and "sig" comprises cryptographic output **107**, i.e., an ECDSA digital signature for compatibility with blockchain-based systems.

Tap-Unique URL Regeneration. In embodiments, tap-unique URL **93** is unique to each tap or powering up of tag **10** and is based on NFC standards and protocols. Each tap or powering up of tag **10** by a PCD device, whether a PCD encoding device **20** or PCD reading device **14**, results in the generation of a new tap-unique URL **93** prior to being read by PCD reading device **14**. For example:

For tags with a random unique identifier feature enabled, a new unique tag identifier **103** is generated for each interaction.

For tags using an interaction counter, tap counter data **105** increments with each tap, ensuring sequential integrity.

By dynamically updating tag data **101** and incorporating it into tap-unique URL **93**—whether encrypted or plain—a secure, unique URL is generated for every interaction.

It is to be understood that when referring to tap-unique URL **93** in embodiments of the invention at various steps in the systems, methods and processes disclosed, tap-unique URL **93** is a dynamic feature or element and may comprise different data and elements at various times. Tap-unique URL **93**, therefore, should be construed and considered in the context of which it is being utilized or discussed. For example, "initial tap-unique URL" **93** (as that term is used herein) is the tap-unique URL that is generated at encoding steps of embodiment process **600**. It comprises the first—and, hence, initial—tap-unique URL **93** encoded on unique individual tag **10** during the encoding process and readies tag **10** to be affixed to its corresponding, respective unique individual product **8**. Afterwards, all subsequent tap-unique URLs **93** (discussed with reference to embodiments of process **700**) are referred to collectively as "subsequent tap-unique URLs" unless noted otherwise.

Step **644**. In embodiments, at Step **644**, encoding module **30** encodes tag **10** with encryption key **99**, thereby providing tag **10** with the ability to generate encrypted tag data **101** upon each tap interaction for a tap-unique URL **93**.

This concludes the encoding steps of embodiment process **600**.

After encoding and encrypting tag **10**, as demonstrated in process embodiment **600**, tag **10** may be affixed to unique individual product **8** for which it was created. FIG. **4** depicts tag **10** affixed to product **8**, a pair of brand sneakers. More specifically, tag **10** is affixed to the box of product **8** (sneakers). In embodiments, tag **10** may be affixed to the product or packing for the product. In embodiments, tag **10** may be manufactured within or otherwise directly inserted within or into, or directly affixed upon, product **8**. For example, with respect to brand sneakers, tag **10** may be inserted or internally affixed to a tongue, side or sole of a shoe. With respect to clothing, tag **10** may be affixed directly upon the clothing or otherwise embedded in a suitable location. Precise placement of tag **10** on product **8** is only limited by the limits or range of NFC technology; otherwise, tag **10** may be placed anywhere on or within product **8**.

FIG. **5** depicts tag **10** affixed to product **8**, brand perfume. In FIG. **5**, tag **10** is affixed over a product packaging seam to serve as monitoring device or seal against tampering. Should the box or packaging of product **8** be opened or otherwise tampered with (e.g., attempting to remove or peel away tag **10** from the box or packaging of product **8**)—thereby breaking the tamper protection feature of tag **10**—monitoring wires in the tag are broken and the tampering event will be recorded according to the tamper feature of tag **10** and reflected in tag tamper status data **109**. When tag **10** is powered up and read by PCD reading device **14** (e.g., a cell phone as depicted in FIG. **5**), tag tamper status data **109** will be read and processed as explained in greater detail, below. In embodiments, tag tamper status data **109** will read that tag **10** has been tampered with, thereby drawing into question the authenticity or integrity of product **8**.

Continuing with FIG. **5**, a perspective view is presented of a consumer end user **12** interacting with encoded NFC tag **10** affixed to the packaging of product **8** by tapping PCD reading device **14** (e.g., a cell phone) close enough to encoded NFC tag **10** to initiate NFC communications with tag **10** in accordance with NFC protocols. Tapping PCD cell phone **14** to encoded tag **10** establishes communication between PCD reading device **14** and encoded NFC tag **10** and verification of product **8** according to embodiments of the invention is initiated.

FIGS. **7A-7C** depict process **700**, a tap/verification embodiment portion of the invention.

Step **702**. In embodiments, at Step **702**, consumer end user **12** taps encoded tag **10** with an NFC-capable PCD reading device **14**, such as a smartphone, in accordance with initialization and communication protocols and standards previously discussed. In embodiments, any suitable PCD reading device may perform the steps of process **700**. Consumer end user **12** may include, for example, a certifying body, governmental agency, manufacturer, distributor, or other party seeking to verify the authenticity, tamper status, or metadata of product **8**.

Step **704**. At Step **704**, in an embodiment, PCD reading device **14** powers tag **10** and reads tap-unique URL **93** encoded on tag **10**. Upon powering tag **10**, in embodiments, and as previously discussed with respect to process **600**, tag **10** generates a new tap-unique URL **93** specific to the powering up of the tag and the unique individual tap interaction. This regeneration ensures the URL is unique for each interaction, i.e., tap-unique URL **93** is specific to the powering up of tag **10** by the unique individual tap interaction (hereinafter, each unique individual tap interaction simply referred to as the "tap interaction").

Step **706**. At Step **706**, in embodiments, upon reading tap-unique URL **93**, a web client **16** (e.g., a web browser) operating on PCD reading device **14** opens tap-unique URL **93**. In some cases, web client **16** may prompt the end user **12** for authorization before proceeding. Upon authorization (e.g., tapping a confirmation button), web client **16** opens tap-unique URL **93** and is directed to the web host portion embedded within the URL in accordance with known protocols.

Step **708**. At Step **708**, in embodiments, opening tap-unique URL **93** triggers web client **16** operating on PCD reading device **14** to send an HTTP GET request **18** to API module **220**. This request includes all data embedded in the URL, such as unique product ID **95**, encrypted tag data **101**, and cryptographic output **107** (e.g., MAC, OTP, or digital signature). In embodiments, examples of tap-unique URLs **93** based on different cryptographic outputs and verification processes, may comprise the following:

NXP 424 DNA URL Example (MAC)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwmCYnxBpqq
EKBqp37azFouZLBG?picc=063792A3AC712E6C7DA789D98BF9CA43&
cmac=BEB842FD38CBD9B8
```

EM4425 URL Example (OTP)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwm
CYnxBpqqEKBqp37azFouZLBG?uid=AAAAAAAAAAA&
token=AAAA&f=A&sig=AAAAAAAAAAAAAAAAAAAAAA
```

Edge TruST25 URL Example (Digital Signature)

```
https://securetap.io/authenticate/tag_MAdxxoGkIdgrrrjwmCYnxBpqqEKBqp37
azFouZLBG?uid=063792A3AC712E6C7DA789D98BF9CA43&
counter=56789&tamper=T&sig=ABCDEFGHIJKLMNopqrstuvwxyz012345
```

Step **710**. At Step **710**, in embodiments, host web server **230** processes the GET request, extracting data from tap-unique URL **93**, such as, for example, unique product ID **95**, encrypted tag data **101**, and cryptographic output **107**. This data is forwarded to API module **220** for further processing and verification. This step, as with all steps of the various process embodiments disclosed herein, need not necessarily be performed immediately after Step **708**. For example, without departing from the spirit and scope of the invention, in an embodiment, Step **710** may be performed after Step **712** or simultaneously therewith. Those skilled in the art will readily appreciate this.

Step **712**. In embodiments, host web server **230** retrieves additional metadata **17** associated with PCD reading device **14** (e.g., geolocation, device IP, or timestamp) and forwards it along with the GET request to API module **220**.

Step **714**. At Step **714**, in embodiments, API module **220** queries database module **302** using unique product ID **95** to retrieve stored data associated with unique individual tag **10** and its corresponding unique individual product **8**. Such data may may include, for example, and not by way of limitation: tag type (e.g., NXP 424 DNA, EM4425, Edge TruST25), cryptographic configuration (e.g., MAC, OTP, or digital signature), associated unique blockchain transaction IDs **97** for prior interactions (e.g., initial unique blockchain transaction ID **97-01**, subsequent unique blockchain transaction ID **97-*n*** (see below)).

In this regard, blockchain transaction ID **97** would comprise blockchain transaction ID **97** of the immediately preceding blockchain transaction **1802**. Referring to FIG. **18**, for example, if tap-unique URL **93** is generated as a result of the first tap transaction following encoding of tag **10** in accordance with process **600**, blockchain transaction ID **97** as per Step **714** would comprise initial blockchain transaction ID **97-01** for initial blockchain transaction **1802-01**, as discussed above in reference to FIGS. **18** and **19**. Continuing with reference to FIGS. **18** and **19**, if tap-unique URL **93** is generated as a result of a second tap transaction following encoding of tag **10** in accordance with process **600**, blockchain transaction ID **97** as per Step **714** would comprise subsequent blockchain transaction ID **97-02** for subsequent blockchain transaction **1802-02**. The process continues to repeat in the same fashion, with each transaction **1802** of a block **1800** being cryptographically linked to a previous block other than block **1800-01** which serves as an initial block in the chain and is not linked to any previous block (as no block exists). Upon each tap transaction of PCD device **14**, blockchain module **302** continues to grow with the addition of a new subsequent transaction **1802-*n*** as recorded in a newly added block **1800-*n*** to the chain and the generation of a new subsequent blockchain transaction ID **97-*n*** (where n is an integer representing the next numeric value (number) of the transaction, block and blockchain ID).

Step **716**. At Step **716**, API module **220** uses the tag type retrieved from the database to determine the correct cryptographic verification process **718**A. For instance, in embodiments, for tags configured with MACs, the stored encryption key **99** is retrieved for validation in cryptographic verification process **718**A. In embodiments, for tags configured with OTPs, the stored token is matched against the one-time password in the URL in cryptographic verification process **718**A. Alternatively, in an embodiment, for tags using digital signatures, the corresponding public key is retrieved for signature validation in the cryptographic verification process **718**A.

In embodiments, and as may be necessary (e.g., for tags **10** configured with MACs using tenant's encryption key **99**), API module **220** sends an encryption key request **87** (with tenant encryption key ID **86**) to KMS **342** to obtain tenant's encryption key **99** to perform tag **10** cryptographic verification process **718**A. In embodiments, API module **220** may obtain tenant's encryption key **99** from database module **302**. In embodiments, API module **220** may obtain encryption key **99** from other suitable and appropriate sources, for example, from encoding module **30**. Encryption key **99** may further be stored within API module **220** according to known methods and processes by those of skill in the art.

FIG. **7**B illustrates an embodiment of cryptographic verification process **718**A. Cryptographic verification process **718**A is intended to comprise tags **10** configured with MACs, as well as tags **10** configured with OTPs and digital signatures. When required, in embodiments, tenant's stored encryption key **99** is retrieved for validation in cryptographic verification process **718**A. To be clear, cryptographic verification process **718**A illustrated in FIG. **7**B is an embodiment of the process, and the invention is not limited to any specific tag type or cryptographic output.

Step **718**A-**02**. At Step **718**A-**02**, in embodiments, API module **220** reads the cryptographic output (e.g., MAC, OTP, or digital signature) from tap-unique URL **93**.

Step **718**A-**04**. In embodiments, at Step **718**A-**04**, using tenant-specific encryption key **99**, API module **220** decrypts the encrypted tag data portion of tap-unique URL **93**. For example, in an embodiment, for tags configured with MACs,

the decryption verifies the MAC tied to tag data **101**. In embodiments, for tags configured with OTPs, the decryption confirms the session-specific token's validity. In embodiments, for tags configured with digital signatures, the decryption validates the signature against the public key.

Step **718**A-**06**. In an embodiment, at Step **718**A-**06**, after decryption, in embodiments, API module **220** reads the decrypted tag data **101**, including, where applicable, unique tag ID **103**, interaction counter data **105**, and tamper status data **109**.

Step **718**A-**08**. In embodiments, at Step **718**A-**08**, API module **220** generates a new cryptographic output **107**A based on the decrypted tag data **101** and the applicable cryptographic method. For example, in embodiments, for tags configured with MACs, API module **220** generates a new MAC using the updated tag data and tenant-specific encryption key **99** to ensure the integrity of the interaction. In embodiments, for tags configured with OTPs, API module **220** validates the session-specific token from the decrypted tag data **101** against the expected OTP and issues a new OTP for future interactions. In embodiments, for digital signature-based tags, API module **220** validates the decrypted digital signature using the public key associated with the tag to ensure the authenticity of the tag data **101**.

Step **718**A-**10** to **718**A-**12**. In embodiments, at Steps **718**A-**10** to **718**A-**12**, API module **220** verifies original cryptographic output **107** from tap-unique URL **93** against newly computed cryptographic output **107**A by comparing the original output **107** with the newly computed cryptographic output **107**A. If output **107**A matches original output **107**, the verification is successful, confirming that unique individual tag **10** is authentic, and its data is untampered. If the outputs do not match, API module **220** determines that tag **10** may have been tampered with or is otherwise invalid.

Steps **718**A-**14** to **718**A-**16**. In embodiments, at Steps **718**A-**14** through **718**A-**16**, API module **220** generates verification result **111**. If the cryptographic outputs match, API module **220** verifies that tag **10** is authentic. If the cryptographic outputs do not match, unique individual tag **10** may be deemed invalid, tampered with, or compromised.

Step **718**A-**18**. In an embodiment, at Step **718**A-**18**, API module **220** records verification result **111** and associated metadata **17** in database module **302** for future reference. This data is associated with or linked to unique individual tag **10** and its respective unique individual product **8** for comprehensive traceability.

In embodiments, at Step **718**A-**18**, in addition to recording tag verification result **111** to database module **302**, API module **220** may further record to database module **302** various other tap interaction data **113**, such as, tag tamper status data **109**, cryptographic output data **107**, various metadata **17** associated with PCD reading device **14** and web client **16** operating on PCD reading device **14**. In embodiments, such additional data transmitted by API module **220** to database module **302** would be associated with unique individual tag **10** and may be used to generate one or more updated data structures **89** from database module **302**. Collectively, all such data associated with a unique tap transaction, including data generated in the verification process, may be collectively referred to as tap-interaction data **113**. It is understood that that tap-interaction data **113** may be modified, added to, deleted from, processed, recorded, stored, and the like and may comprise different data or sets of data (with respect to a unique tap transaction) at different steps in embodiments.

Step **720**. In an embodiment, at Step **720** API module **220** transmits verification result **111** to blockchain module **322** to record the transaction. In an embodiment, for example, a JSON RPC request or other similar remote procedure call request as previously discussed to blockchain module **322** to record tap-interaction data **113**. In embodiments an additional one or more tap-interaction data **113** is also transmitted by API module **220** to blockchain module **302** for recording in connection with the unique tap transaction.

Step **722**. In embodiments, at Step **722**, blockchain module **322** records verification result **111** thereby generating subsequent unique blockchain transaction ID (hash) **97** for transaction. In an embodiment, tap-interaction data **113** may also be recorded in the same transaction. Recording of verification result **111** and, in embodiments, tap-interaction data **113**, to blockchain module **322** is performed in the same or substantially similar fashion as that previously presented with respect to recording data structure **89** at Step **624** (in that case, an initial transaction **1802-01**). With regard to the process disclosed at Step **624**, and with reference to FIGS. **18** and **19** (as previously discussed), recording verification result **111** and, in embodiments, tap-interaction data **113**, on blockchain module **322** would comprise a subsequent transaction **1802**-*n* recorded in a newly added block **1800**-*n* to the chain, thereby generating a new subsequent blockchain transaction ID **97**-*n* and updating the blockchain ledger.

Step **724**. In embodiments, at Step **724**, blockchain module **322** transmits unique blockchain transaction ID **97**-*n* for recording verification result **111** (and, in embodiments, a one or more tap-interaction data **113**) to API module **220**. Transmittal of blockchain transaction ID **97**-*n* for subsequent transaction **1802**-*n* is in response to transaction request **83** transmitted by API module **220** at Step **720**.

Step **726**. In an embodiment, at Step **726**, API module **220** receives unique blockchain transaction ID **97**-*n* from blockchain module **322**.

Step **728**. At Step **728**, in embodiments, API module **220** updates database module **302** with unique blockchain transaction ID **97**-*n* and verification details. This ensures an immutable and verifiable record of all tag interactions. In embodiments, at Step **726**, API module **220** records unique blockchain transaction ID **97** for recording verification result **111** (and, in embodiments, tap-interaction data **113**) to database module **302**. As with all data transmitted by API module **220** to database module **302** with respect to unique individual tag **10** and unique individual product **8**, all subsequent unique blockchain transaction IDs **97** may be stored, saved and incorporated into database module **320** in connection or association with unique individual tag **10** and its unique individual product **8**. Importantly, in embodiments, each time unique individual tag **10** is tapped or read by PCD reading device **14**, the steps of process **700** are initiated and repeated, with specific verification result **111** and tap-interaction data **113** arising or generated from each individual tap transaction recorded to blockchain module **322**. In addition, a unique subsequent blockchain transaction ID **97**-*n* is generated for each tap transaction, thereby creating an immutable record of every tag tap transaction and its associated tap-interaction data **113**.

Step **730**. At Step **730**, in an embodiment, API module **220** may generate a verification certificate **115**. Verification certificate **115** may comprise data including, but not limited to verification result **111**, unique blockchain transaction ID **97**-*n*, cryptographic details (e.g., MAC, OTP, or digital signature), and various metadata **17** associated with PCD reading device **14**, unique individual tag **10**, unique individual product **8**, and/or the unique tap interaction. Additional tap-interaction data **113** may further comprise interaction counter data **105** and tag tamper status data **109**.

Verification certificate **115** may take various forms. For example, verification certificate may comprise a digital graphic file (e.g., jpeg, png, etc.), a PDF file, a hyperlink linked to a web page using HTML or other suitable format. The objective of verification certificate **115** is to provide an end user **12**, tenant, or a certificate issuing authority, such as a governmental agency seeking to verify the authenticity of goods or products, with visually readable evidentiary indicia as to the authentication of the good or product. In embodiments, verification certificate **115** may be downloaded and/or otherwise saved to PCD reading device **14**, emailed from a web client **16** interface operating on PCD reading device **14**, transmitted via text (e.g., SMS communication) or saved, communicated and transmitted in any number of ways for use with digital files that are generally known among cell phone users and those skilled in the art.

Step **732**. Continuing, in embodiments, after generating verification certificate **115**, API module **220** transmits verification certificate **115** to PCD reading device (e.g., cell phone) **14** of end user **12**, thereby providing end user **12** verification regarding unique individual tag **10** and unique individual product **8** to which tag **10** is affixed. In all cases, end user **12** is to be construed as any individual or party seeking to verify the authenticity of product **8** for any reason whatsoever.

FIGS. **6-7** (processes **600** and **700**, respectively, and inclusive of cryptographic verification process **718**A) illustrate flowcharts of various methods and processes for functionality associated with portions of embodiments of the invention based on the schematic of FIG. **1**. While the various steps in the flowcharts are presented and described sequentially, one of ordinary skill will appreciate that some or all of the steps may be executed in different orders and some or all of the steps may be executed in parallel. Further, in one or more embodiments of the invention, one or more of the steps described below may be omitted, repeated, and/or performed in a different order. Accordingly, the specific arrangement of steps shown in FIGS. **6-7** should not be construed as limiting the scope of the invention. This is particularly so as the schematic of FIG. **1** may be amended and modified numerous ways without departing from the scope of the invention. The schematic of FIG. **1** and the processes and methods of FIGS. **6-7** are illustrative of embodiments and comprise various features and elements that may not be necessary to carry out the claimed invention.

FIG. **8** is a schematic of a tap/verification configuration **800** of a portion of an embodiment of the invention depicting the various component parts and steps utilized in process **700** and the interconnectivity of those components, elements and steps. FIG. **8** is to be viewed with the discussion of process **700**. To avoid repetition, the steps comprising process **700** will not be repeated.

In an embodiment, with reference to FIG. **8**, local encoding device **40** comprises encoding module **30** operating thereon as well as tracking module **36** also operating thereon. As discussed further within, tap-interaction data **113** generated with each tap and collected, compiled or organized by API module **220** may be transmitted by API module **220** to one or more devices functionally connected to API module **220** and capable of receiving tap-interaction data **113** for use, analysis or processing. In embodiments, tap-interaction data **113** may be transmitted to tracking module **36**, in this case, operating on the same device **40** as encoding module **30**. In embodiments, API module **220** may transmit tap-interaction data **113** to local tenant device **60** where a tenant may view that data. Tap-interaction data **113** may comprise valuable information concerning a tap transaction, such as, for example (in addition to tag verification result **111**), the geographic location of the tap transaction, the precise date and time of the transaction, various metadata **17** associated with PCD reading device **14**, web client **16** operating thereon, and/or of user **12**, and other logistic and marketing-based information that may be of value to the tenant. Such other forms of data will be apparent in view of further discussion of the drawings.

FIG. **20** is an example of tap-interaction data **113** compiled for use and storage to database module **302**. In the example of FIG. **20**, tap-interaction data **113** comprises unique tag identifier **103**, unique product ID **95**, date of creation of tag **10**, date of tap transaction, the IP address of PCD reading device **14**, various metadata **17** collected from web client **16** operating on PCD reading device **14**, tag verification result **111**, tag tamper status data **109**, and latitude and longitude of the tap interaction. The above list is not exhaustive and is intended to present examples of data comprising tap-interaction data **113** and should not be construed as limiting the scope of the invention. (For clarity, various software code terms as demonstrated in FIG. **20** may not be identical to the terminology used herein. For example, the software code term "tag_id" is not to be construed as tag UID **103** as used in this disclosure; rather, that software code term may equate with the term "unique product ID **95**" as used herein.)

FIG. **21** (to be viewed with FIGS. **18** and **19**) depicts an example of subsequent blockchain transaction **1802-02** for tap-interaction data **113** in accordance with various embodiments. Transaction **1802-02** is recorded in subsequent block **1800-02** and tap-interaction data **113** is recorded in block **1800-02**. In the example of FIG. **21**, tap-interaction data **113**, as recorded in block **1800-02** for transaction **1802-02**, comprises the following data features or elements: id (a unique identifier for each tap interaction); tag_id (links to the related tag in the tags table); date_created (timestamp when the tap interaction was created); last_updated (timestamp of the most recent update (defaults to the current time); ip_address (IP address from which the interaction originated); metadata (additional request metadata in json format (optional), such as device type, web browser, etc.); is_verified (indicates whether the tap interaction for tag has been verified); is_tampered (indicates whether the tag has been tampered with); latitude & longitude (geographical coordinates (optional)). In the example of FIG. **21**, a unique identifier for each tap transaction may be generated by API module **220** upon reading of each tap-unique URL **93** resulting from its corresponding tap interaction (hereinafter, the "tap-unique ID" **91**). It is to be understood that in embodiments, tap-unique ID **91** may comprise tap-unique data **113**. The above is not exhaustive of examples comprising tap-interaction data **113** that may be recorded to blockchain module **320** for a tap interaction and should not be construed as limiting the scope of the invention.

FIG. **9** depicts a sample tenant user interface of an embodiment of the invention wherein a tenant may request one or more unique individual encoded tags **10** for one or more unique individual products **8**. In an embodiment, referring to Step **602** of process **600**, a tenant user may submit a tag order request **62** through tenant interface module **260** for at least one unique individual tag **10** (for authentication or other purposes, such as, for example, obtaining product information) for at least one unique individual product **8**. The tenant interface module **260** of FIG. **9** is feature packed and provides the tenant with numerous options to customize various product data **70** to be made available to end user **12** upon tapping unique individual tag

10 associated with unique individual product 8. In an embodiment, tenant interface module 260 may provide a projected view 260-01 of a tag tap for a brand shoe product that may be viewed by end user 12 when tapping respective unique individual tag 10 for that product. In the embodiment illustrated, projected tap review 260-01 allows the tenant to preview and customize an interface view of a tag verification result 111 that may be generated by API module 220 and read by end user 12 on end user's PCD reading device 14. While not specifically discussed in the steps comprising process 700, it is understood that upon completion of the verification Steps 718A 14 through 718A 18, API module 220 may generate and return to PCD reading device 14 (through for example, web host server 230) a tag verification result interface or display using HTML or any suitable format or protocol (a "verification display 92"). It is understood that that the transmittal of verification display 92 for viewing by end user 12 on PCD reading device 14 may apply to all embodiments of the invention. Note that verification display 92 is not the same as verification certificate 115, discussed below. Verification display 92 provides end user 12 with immediate access to and viewing of verification result 111. It is to be further understood that that generation and transmittal of verification display 92 may take place in embodiments at any time subsequent to Step 718A 16, when API module 220 verifies unique individual tag 10 and generates tag verification result 111.

Continuing with FIG. 9, the illustrated interface allows tenant user to configure a consumer tap interface, which, in embodiments, may generate a verification display 92 and/or a corresponding verification certificate 115. In embodiments, customizable options available to a tenant for use with an end user 12 for use in verification display 92 and/or verification certificate 115 may include: company information, product image and identification, authentication request button, obtain certification button (for example, to download the certificate to the user's cell phone), product details, link to company's website for product, product video, or any other relevant information that a tenant may desire end user 12 to view when tapping tag 10 affixed to product 8.

FIG. 10 depicts a sample page or tab of a website embodiment of tenant user interface module 260 wherein a tenant may review one or more products 8 to which encoded tags 10 have been affixed and further depicting various end user 12 tap-interaction data 113 for each such unique individual tag 10 and its respective unique individual product 8. As depicted in FIG. 10, an embodiment of tenant user interface module 260 allows the tenant to view discrete, unique individual products 8 that have unique individual encoded tags 10 affixed thereto for monitoring by tenant: Glamour Glasses, serial no. 15A (15 total taps) (260-02); Hi Flier Court Shoes, serial no. HF-100AA white (82 total taps) (260-03); Jump Phone X 5+, serial no. JZP-X-2024 5+ (7 total taps) (260-03); Jump Pro Notebook 7, serial no. JPN-2024-7 (765 total taps) (260-04); and Canal No. 9 perfume, serial no. Ca_05/1355 (12 total taps) (260-05). Each of the example products 8 are specific, individual items to which a unique tag 10 has been affixed. Data displayed in the embodiment of interface module 260 may comprise, in whole or in part, tap-interaction data 113 for each tag 10/product 8 combination, the substance of which may be recorded, in whole or in part, to blockchain module 322 in embodiments as described earlier herein. Unique blockchain transaction IDs 97 may also be displayed in the interface embodiment of FIG. 10, along with any other data concerning each blockchain transaction 1802 and one or more data structures 89 associated with each unique individual tag 10 and its associated unique individual product 8. It is to be understood that that the webpage or tab of the embodiment of interface module 260 is not limited to the data depicted therein. This understanding applies to all of FIGS. 9-16. In embodiments, through the interfaces depicted in FIGS. 9-16, the tenant may access tap-interaction data 113, product data 70, data structures 89, tag-based data, and any other data comprising database module 302 and blockchain module 322, in whole or in part, with respect to unique individual tag 10 and its respective unique individual product 8 and tap-interactions associated therewith.

FIG. 11 depicts a sample page or tab of a website embodiment of tenant user interface module 260 wherein a tenant may search for one or more tags order requests 62 for one or more tags 10 to be used for one or more products 8 according to embodiments of the invention and discussed previously in the disclosure. In the interface embodiment of FIG. 11, a tenant user may perform a free form text search for one or more tag order requests 62 by entering various data associated with the one or more orders into search box 260-07. Such data may comprise any data associated with an order, for example and not by way of limitation, tag order request 62 number or other identifier of a particular tag order request 62, a product identifier (e.g., universal product codes or UPC codes, bar codes, product serial number, quick response or QR codes (or any other type of two-dimensional matrix barcode), electronic product or EPC codes, GS1 DataMatrix codes, GS1 DataBars, ITF-14 codes, Code 128, RFID tag data and/or European Article Number or EAN codes, or any such other product identifier that may be used by a tenant with respect to product 8), product name, or any other product data that a tenant may use with respect to product 8. In addition, in embodiments of the interface 260 of FIG. 11, one or more drop-down buttons or menus 260-08 may be implemented for use by the tenant to review data associated with the drop-down menu name or variable. In the interface embodiment of FIG. 11, depicted are drop-down menus 260-08 for the parameters: order ID, product name, tag (or product) type, tag (or product) size, tag (or product) color, number of tags (or products) and date of the order. In embodiments, drop-down menus 260-08 of interface 260 may be customized by the tenant to include numerous related parameters that may be used in association with tag order requests 62 and tags 10 and products 8 associated therewith.

FIG. 12 depicts a sample page or tab of a website embodiment of tenant user interface module 260 wherein a tenant may create a tag order request 62 for one or more unique individual tags 10 to be encoded for one or more unique individual products 8. In the interface embodiment of FIG. 12, a tenant user may select product 8 from a previous tag order request 62 as illustrated at 260-09. In embodiments, interface 260 may directly interface with a catalog of one or more products 8 previously defined by the tenant and submitted to API module 220 through interface module 260 or as may be defined and catalogued by tenant on local tenant device 40. In embodiments, selection of product 8 may be performed by entering text in box 260-09 or selecting from a drop-down menu. Continuing with FIG. 12, in embodiments, tenant may select tag 10 shape via drop-down menu 260-10 and tag size via drop-down menu 260-11. The available shapes and sizes of tags 10 may vary according to tag manufacturer. In an embodiment, the tenant may enter the exact number of tags 10 to be encoded depending on the number of products 8 for a batch encoding in box 260-12. In embodiments of tag order request 62 interface 260, the

tenant may upload one or more graphic designs to be printed on the tags **10** via the graphic design upload box **260-13**. File types that may be uploaded may include any type of graphic or image file commonly used for such purposes (e.g., jpeg, jpg, png, pdf, etc.). In embodiments, the graphic design may be printed prior or subsequent to the tag encoding process as illustrated in an embodiment at **600**. In an embodiment of tag order request **62** interface **260**, an "additional notes or instructions" box **260-14** may be included wherein the tenant may provide additional notes or instructions concerning tag order request **62**. Finally, in an embodiment, when satisfied that all data fields of tag order request **62** interface **260** are accurate, tenant may submit the tag order request by clicking or executing the "place order" button or function **260-15**. Upon clicking or executing place order button **260-15**, tenant's tag order request **62** is submitted to the creator or manufacturer of tags **10** for tenant's products **8**.

As previously discussed, embodiments of the invention need not necessarily require that the tenant of products **8** and the manufacturer of tags **10** be separate and distinct entities. It is to be understood that the tenant and the creator or manufacturer of the tags may be the same entity or party. A large brand producer of products, for example, may desire to create its own tags. In such cases, the brand producer may implement the various functions, features and elements of interface **260** directly to the encoding process without using any third party and without need for tag order request **62** to that party. Those of skill in the art would appreciate that embodiments of the invention may be implemented in numerous ways and that specific embodiments disclosed herein may be deviated from without departing from the scope of the invention. This is just one example.

FIG. **13** depicts a sample page or tab of a website embodiment of tenant user interface module **260** depicting an order confirmation generated by the interface in response to a tag order request **62** submitted by a tenant, for example, with respect to the embodiment of FIG. **12**. A tag order confirmation may be in response to tag order request **62** for one or more unique individual tags **10** for use with one or more unique individual products **8**. In the interface **260** embodiment of FIG. **13**, the order confirmation depicts various information concerning tag order **62** for viewing by the tenant. In embodiments, for example, tag order confirmation of interface web page may comprise or include: a tag order number (tor_kuOjHSlyXGYlgCdXh) (in embodiments, generated, for example, by API module **220**) **260-16**; order date (Sep. 6, 2024) **260-17**; product name (Shades of Envy Sunglasses) **260-18**; product ID (as per tenant, not to be confused with unique product ID **95**) (prod_K5G7Yf5) **260-19**; tag order status (pending) **260-20**; invoice payment status (by tenant on invoice by tag provider for tag order) (no) **260-21**; product image **260-22**; tag type (NTAG424) **260-23**; tag shape (rectangle) **260-24**; tag size (2×3) **260-25**; tag quantity (2,000) **260-26**; last updated (Sep. 6, 2024) **260-27**. In embodiments, various other information may be displayed in the tag order confirmation of interface web page **260** of FIG. **13** and the embodiment of FIG. **13** is not limited to any specific order data. In embodiments, the tag order confirmation interface of FIG. **13** may be generated by API module **220** upon receipt of tag order request **62**. Alternatively, in embodiments, the tag order confirmation may be generated by a module or software running or operating on local device **40** or any other computing device, e.g., a server, etc., that may require approval of order request **62** by a manufacturer or producer of the tags in response to order request **62**.

FIG. **14** depicts a sample encoding interface of an embodiment of encoding module **30** depicting a batch encoding in progress of one or more unique individual encoded tags **10** for one or more unique individual products **8**. The interface embodiment of FIG. **14** depicts a batch encoding of 5,000 unique individual tags **10** in progress in accordance with, as an example, process embodiment **600**. The interface page of encoding module **30** in FIG. **14** is the "encode" page **30-01**. Additional tabs or pages of the interface of encoding module **30** may comprise, but are not limited to: settings page **30-02**, help page **30-03** and account page **30-03**. A user of encoding module **30** may toggle and move about the various tabs or pages comprising the interface according to the needs and requirements at the time. For example, by accessing account page **30-03**, a user may view, obtain, enter, edit, modify, amend or delete various account information relative to the tenant. Settings page **30-02** may comprise various settings and administrative controls for use in encoding tags, interacting with API module **220**, and any other control aspect for implementing or executing embodiments of the invention according to specific needs, desires and requirements based on tag type, size, encoding, encryption, and the like.

Continuing with the interface embodiment of encoding module **30** depicted in FIG. **14**, additional information that may be displayed with respect to the tag order include but is not limited to: product **8** name (Shades of Envy Pro Celeb 100) **30-06**; tag type (NTag 424 DNA) **30-07**; batch tag number count (5,000) **30-08**; and product **8** image **30-09**. The encoding interface embodiment of encoding module **30** further comprises various status data **30-10**, which, in the embodiment illustrated, depicts that 1,758 tags of the 5,000 batch have been encoded (and encrypted, according to embodiments), representing 35.16% of the batch job having been completed. In addition, status data **30-10** comprises a timer which shows that batch encoding job has been running for 13 minutes, 56 seconds. Lastly, batch encoding status data **30-10** depicts a status bar presenting a graphic representation of the amount of batch encoding job completed and the amount remaining.

The interface embodiment of encoding module **30** depicted in FIG. **14** may present or display additional information concerning each of the 5,000 tags undergoing batch encoding **30-10**. Included in that data is unique product ID **95** assigned to each tag **10** (depicted as "UID" in the illustration), the timestamp as to when each unique individual tag **10** was encoded (depicted as "timestamp" in the illustration), a status indicator, which, in the embodiment depicted, shows that each tag was properly "encoded" (depicted as "status" in the illustration). In embodiments, the tag encoding status indicator may indicate "fail" or other similar term in the event a particular tag **10** failed (for any reason) to be encoding during the encoding process. Continuing with the interface embodiment of FIG. **14**, concerning the tag appearing at the top of the list in the illustration, the timestamp of encoding tag **10** is "2024 Sep. 10 09:41:35" meaning the tag was encoded on Sep. 10, 2024 at 09:41:35. Time may be UTC time or it may be adjusted by a user of encoding module **30** by accessing the settings page or tab **30-02** to set according to any desired time zone. Continuing with the tag appearing at the top of the list in the illustration, the unique product ID **95** assigned to tag **10** is "04A224B1C0001" and the status of the tag is "encoded", meaning that tag **10** has been properly encoded and is functioning properly.

Further included in the interface embodiment of encoding module **30** is a "search records" tool **30-12** allowing a user

of encoding module **30** to search data and records as to all encoding functions performed through the module. For example, a user may be able to search for a specific order number (see, e.g., **30-05**) or tag type (see, e.g., **30-07**) or unique product ID **95** (see, e.g., identifiers listed under UID). These are but a few examples of the many variables that may be searched with search tool **30-12**. Also depicted in the interface embodiment of FIG. **14** is a "search logs" tool **30-13** and a page display find function **30-14** where a user may toggle forward and backward through the page displays of all tags **10** undergoing batch encoding. For example, in FIG. **14**, the total number of tags undergoing batch encoding is 5,000. In the embodiment, each page display shows the ten (10) most recently encoded tags. A user may desire to locate a tag undergoing encoding in the batch encoding operation that is not displayed on the current display page. By selecting a specific display page, the user may locate the tag information as desired.

FIG. **15** depicts an interface of a tracking module **36** depicting tap interactions by end users **12** with one or more unique individual encoded tags **10** for one or more unique individual products **8** including precise geolocation(s) for each tap as displayed on a map. In the embodiment of FIG. **15**, tracking module **36** comprises a portion of tenant interface module **260**. In embodiments, tracking module may be combined with tenant interface module **260**. In embodiments, tracking module **36** may be operable on local tenant device **60**, mobile tenant device **68** or any combination thereof. In embodiments, tracking module **36** may be combined with encoding module **30** or may otherwise be operable on encoding module device **40**. In embodiments, tracking module may be combined with any interface module or otherwise accessible by any combination of the foregoing.

Continuing with FIG. **15**, in embodiments, tracking module **36** provides various tap-interaction data **113** with respect to a particular tag **10** affixed to product **8**. In the tracking module **36** interface embodiment of FIG. **15**, numerous data is provided for tag **10**. The interface of tracking module **36** in FIG. **15** comprises a navigation bar **36-01** with interface tabs: Dashboard, Products, Tags, Order Tags, and Ledger. The interface tab displayed in FIG. **15** is that of a specific tag **10** that was selected from the Tags tab. Continuing, under the heading "Tag Details" **36-02**, unique product ID **95** or tag UID **103** may be displayed depending on the configuration setting as established by a user. In the embodiment illustrated, unique product ID **95** is displayed under "Tag Details" and reads "Tag_FBjREaKaJ6pZcHbOpuUuyNhZ7GgRIxo32xINBWJu". Under the heading "Tag Information," information regarding unique individual tag **10** is provided in the embodiment depicted: "Created" (date and time created) (09/17/2024, 1:38 PM (UST)) **36-03** and "Total Taps" (number of tap interactions) (3) **36-04**. That is, in the interface embodiment depicted in FIG. **15**, unique individual tag **10** for unique individual product **8** has been tapped or subject to tap interactions a total of three (3) times as of the time the data is accessed. Under the heading "Associated Product" various information regarding unique individual product **8** is depicted: "Name" (product name) (Sleek Sunglasses) **36-05**; "ID" (tenant's product identifier, which may comprise a serial number, UPC, etc. as previously discussed) (prod_Ou4pHFoDa3hX6BrOJ) **36-06**; and "view product" button **36-07**, wherein an embedded link, when accessed or clicked by a user, will open a web page, box, pop-up, a further page of interface module **260**, and the like, where additional information may be viewed, accessed or obtained for product **8**. In embodiments, any data comprising product data **70** may be presented in the interface of FIG. **15**.

Continuing with FIG. **15**, in the depicted tap tracking interface, the three (3) tag interactions are geographically depicted on a portion of map **36-08** (Interaction Map). In the depiction, the locations of the three tap interactions are Denver and Colorado Springs, Co, and Las Vegas, NV. As demonstrated above, geographic location of a tap interaction (e.g., longitude and latitude) comprises, in part, tap-interaction data **113** and may be obtained from PCD reading device **14** based on the device's GPS location, cell-based location (as per known cell tower triangulation methods and processes) or any other method, technique or process known in the art for determining cell phone locations. The tap interactions plotted on interaction map **36-08** appear under the heading "Global distribution of tag interactions" and in an embodiment all tap interactions with specific unique individual tag **10** may be plotted on interaction map **36-08**. In embodiments of the interface, a user may select or toggle between an "interactions" view **36-09** or an "analytics view" **36-10** to view more detailed information regarding one or more tap interactions for specific unique individual tag **10**.

FIG. **16** depicts a sample tenant user interface of an embodiment of the invention providing details of an end user tap interaction for an encoded tag **10** affixed to a product **8**. In embodiments, the tap interaction details interface may be accessed, for example, by selecting or clicking the "analytics view" **36-10** of embodiment interface depicted in FIG. **15**. Or, in an embodiment, the tap interaction detail interface may be accessed, for example, by selecting or clicking a pin plotted on interaction map **36-08** of FIG. **15**. Alternatively, in embodiments, specific tap interaction detail may be accessed by any number of common means and methods that would be known to those skilled in the art concerning detailed information regarding a cell phone tap interaction occurring at a geographic location. In the embodiment of FIG. **16**, tap interaction details **36-11** include, but are not necessarily limited to, the following data: tap-unique ID **91** ("tap_JmKAIfYmBXFvaPNG7xlwJAMOWq2172odL6GoXWeBL"); IP Address (IP address of PCD reading device **14** at the time of the tap interaction) ("69.139.56.240"); Verified (tag verification result **111**) ("YES"); Tampered (tag tamper status data **109**) ("NO"); Latitude (geographic latitude of PCD reading device **14** at the time of tap interaction) ("26.5629"); Longitude (geographic longitude of PCD reading device **14** at the time of tap interaction) ("−81.9495); Date (date of tap interaction) ("Date: Sep. 12, 2024"); and Time (time of tap interaction) ("3:42:21 UST"). In embodiments, tap-unique ID **91** may be generated by API module **220** as discussed in the disclosure or tap-unique ID **91** may comprise of unique blockchain transaction ID **97** generated by blockchain module **322** at the time tap-interaction data **113** is recorded to the blockchain in accordance with embodiments discussed herein. In embodiments, tap-unique ID **91** may be generated by API module **220** upon receiving GET request **18** from PCD reading device **14**. In embodiments, tap-unique ID **91** may be transmitted by API module **220** to database module **302** and saved therein with respect to unique individual tag **10** and unique individual product **8**. In embodiments, tap-unique ID **91** may comprise tap-interaction data **113** and provided in transaction request **83** for recording in blockchain module **322** in connection with the tap transaction and in accordance with embodiments previously discussed. Note that the latitude and longitude data of the tap interaction the subject of FIG. **16** is to a location in Cape Coral, FL.

Embodiments of tenant user interface may comprise additional visualizations of tap interactions as follows:

Time Series Analysis: Implement visualizations to display the number of interactions over different time periods (hourly, daily, weekly, monthly) to identify peak usage times and seasonal trends.

Geographic Distribution: Utilize choropleth and cluster maps to illustrate the density of interactions or asset locations across various regions.

Product Movement Tracking: Integrate Sankey diagrams and flow maps to visualize the flow of products through different stages or locations.

Customer Interaction Insights: Use demographic breakdowns and customer retention rate charts to tailor marketing strategies and improve customer engagement.

Performance Metrics: Develop visualizations for tag authentication success rates and response time analysis to ensure optimal performance and customer satisfaction.

Inventory and Asset Management: Display current inventory levels and asset lifecycle stages to aid in elective management and lifecycle planning.

User Engagement Metrics: Illustrate stages of user engagement and interaction heatmaps to optimize user journeys and enhance user experience.

Comparative Analysis: Implement charts to compare interactions across different products, regions, or time periods for better performance evaluation.

Predictive Analytics: Develop forecasting models and tools to identify and visualize emerging trends in interactions or asset movements.

Anomaly Detection: Use visual tools to highlight unusual interaction patterns or locations, enabling timely interventions and risk management.

FIG. **17** depicts a sample verification certificate **115** issued in response to a tap interaction by end user **12** verifying the authenticity of product **8** to which an encoded tag **10** has been affixed. In embodiments, as depicted and described in Steps **730** and **732**, upon verification or authentication of tag **10** at cryptographic verification process **718**A, verification certificate **115** may be transmitted to PCD reading device **14** (or other devices, such as, for example, local tenant device **60** or local encoding device **40** or any combination thereof). Alternatively, in embodiments, verification display **92** may be transmitted. Sample verification certificate **115** of FIG. **17** is illustrative of an embodiment and of various tap-interaction data **113** and/or various product data **70** that may comprise verification certificate **115**. In an embodiment, the sample verification certificate **115** of FIG. **17** comprises three portions: Product Details **115-01**, Blockchain Information **115-02**, and Technical Details **115-03**. In an embodiment, the Product Details **115-01** portion sample verification certificate **115** of FIG. **17** comprises, but is not limited to, information such as: Issued On (when tag **10** was encoded for product **8**) ("Apr. 15, 2024 at 6:42 AM (UTC)"); First Tap (when tag **10** received its first tap interaction) ("Apr. 15, 2024 at 6:42 AM (UTC)"); Total Taps (total number of tap interactions for unique individual tag **10**) ("1387"); Tag ID (in an embodiment, unique product ID **95**; alternatively, in embodiments, tag UID **103**) ("Tag_hOBSjxOJOW8KnFa4wTyYHOQ KsYSokdjk9gDknnTYx"); Issued By (entity or party issuing verification certificate **115**) ("SecureTap Authenticity Services"). In an embodiment, the Blockchain Information **115-02** portion sample verification certificate **115** of FIG. **17** comprises, but is not limited to, information such as: Creation Hash (blockchain transaction ID **97**) ("67d4240173a4ac4732 eeac6d6df8061546Ob615a70010a65e9887c7 dc865f8da"). In an embodiment, the Technical Details **115-03** portion sample verification certificate **115** of FIG. **17** comprises, but is not limited to, information such as: Tag data **101** (PICC data **101** in the embodiment depicted, in encrypted form) ("0B1235FB4F906036303DACB16D568884") and cryptographic output **107** (CMAC data **107** in the embodiment depicted) ("541FFD6BC7DC4AA2"), both of which are specific to the tap interaction resulting in verification certificate **115**. Additional information that may comprise verification certificate **115** include message authentication codes (MACs) (a secure hash generated using a shared secret key to ensure data integrity and authenticity), one-time passwords (OTPs) (a dynamically generated session-specific token to provide one-time validation and prevent replay attacks) and digital signatures (an elliptic curve digital signature). Continuing, sample verification certificate **115** of FIG. **17** further comprises various options **115-04** to end user **12** to obtain or receive additional copies of verification certificate **115**, including, but not limited to, receiving a certificate via text (SMS), downloading a PDF copy of the certificate, or receiving a copy of the certificate by email.

FIG. **24** depicts an illustration of a brand product **8** with encoded tags **10** embedded within the product. Specifically, FIG. **24** depicts a brand electric guitar depicting possible placement options for encoded tags **10** to be inlayed, embedded, affixed, adhered or otherwise attached onto or within the guitar (for example, as decorative medallions or artistry) for use in accordance with embodiments described herein. For example, tag **10-1** is affixed or imbedded into a body portion **8**-A of brand electric guitar **8**. Tag **10-2** is affixed or imbedded in an alternative location between the neck and middle pickups of brand electric guitar **8**. Since guitar necks **8**-B may be replaced and present a second unique product from the guitar body **8**-A (with separate and unique value), tag **10-3** is affixed or imbedded in a headstock location of the neck where it would not interfere with playing, tuning or neck truss rod adjustment by an end user **12**. The example of FIG. **24** is to demonstrate the numerous placement options of tags **10** within or on products **8** to ensure the ability to verify authenticity of the product throughout its life and creating an immutable record or ledger in blockchain module **322**.

In embodiments, tag **10** may comprise the NXP NTAG213. Specific information regarding the NTAG213 may be found in the product's data sheet, the contents of which are incorporated herein by reference in their entirety herein. The NTAG213 data sheet is available at https://www.nxp.com/docs/en/data-sheet/NTAG213_215_216.pdf.

In embodiments, tag **10** may comprise the em|echo-V 4425 tag by EM Microelectronic (the "EM4425 Tag"). The EM4425 Tag is a combined RAINFC based tag directed to HF, NFC, and RAIN RFID™ technologies. The 4425 microchip in the EM4425 Tag combines all functionalities on a single die, with NFC for proximity range, HF for vicinity range, and RAIN technology used for long range application purposes. The EM4425 Tag is an example of a combined NFC/RFID tag allowing for numerous embodiments of the invention.

As to additional embodiments, EPCs (electronic product codes) have become increasingly popular in retail, healthcare, supply chain, and logistics businesses as it provides a unique digital ID to various assets using small RFID labels. Unlike barcode and QR Code technology, multiple RFID-tagged items can be scanned and tracked at once, from a distance of up to 15 meters (approximately 49 feet) with a clear line of sight. NFC technology (13.56 MHz), on the

other hand, is best suited for close interactions. While UHF Passive RFID technology (860 MHz-960 MHz), also known as RAIN RFID is mostly used in Business-to-Business (B2B) settings, allowing for track and trace, inventory management, order fulfillment, NFC technology/HF RFID is mostly used in close proximity, customer-centric B2C environments. A dual NFC/RFID combined tag provides for both close proximity tap interactions, as expressly disclosed herein, and longer range interactions, such as those commonly associated with EPC-RFID interactions.

The EM4425 Tag, for example, features an RFID chip that combines the features of RAIN RFID technology with NFC and HF RFID for a standalone tag. The integration of RAIN RFID and NFC technologies on a single integrated circuit chip led to the development of RAINFC, a powerful combination that offers a wide range of benefits and applications in various businesses including retail and healthcare. With RAINFC, embodiments of the invention feature RAIN RFID for long-range applications (such as inventory control), HF for vicinity, and NFC for proximity-range applications, such as those disclosed in detail herein. The EM4425 chip in the EM4425 Tag provides a seamless convergence of these two technologies, allowing for enhanced connectivity, data storage, and security. Additionally, the chip in the EM4425 Tag incorporates advanced AES-28 encryption and authentication mechanisms, ensuring the integrity and confidentiality of stored data, especially in NFC transactions.

In embodiments, the EM4425 Tag, or any other suitable combined RFID/NFC tag may be used. A combined RFID/NFC tag **10**, such as the EM4425 Tag, would meet all the features of the disclosed embodiments and provide additional RFID/RAINFC based features. The applications are numerous and may be briefly summarized as follows (based on documentation concerning the EM4425 Tag):

Smart Retail. For example, RAINFC facilitates smart retail applications such as inventory management, product authentication, and personalized marketing. The EM4425 Tag, for example, enables the storage of detailed product information, including origin, expiration dates, and unique identifiers, ensuring product authenticity and traceability. NFC-enabled smartphones may interact with RAINFC tags to provide consumers with product details, promotions, and loyalty rewards, enhancing the retail experience.

Supply Chain Optimization. RAINFC may be used in supply chain operations by enabling real-time tracking, authentication, and data exchange. From warehouse management to shipping and delivery, the integration of RAIN RFID and NFC technologies enhances visibility, security, and efficiency throughout the supply chain, reducing errors and improving overall performance.

Healthcare Management. In the healthcare sector, RAINFC supports applications such as patient identification, medication tracking, and equipment management. Security features in the EM4425 Tag chip, for example, ensure the integrity of patient data, while NFC-enabled devices enable healthcare professionals to access and update medical records securely, streamlining processes and improving patient outcomes and patient care.

Access Control and Security. RAINFC technology employing the dual frequency EM4425 chip is utilized for access control systems, asset tracking, and secure authentication in various environments, including corporate offices, educational institutions, and event venues. The EM4425 IC's ability to store and protect sensitive data, combined with the seamless interaction offered by NFC, enhances security and convenience for users.

In embodiments, using a dual frequency combined RFID/NFC tag **10**, such as the EM4425 Tag, tenants may tag their products **8** and assets with RAINFC tags **10**, allowing end users to authenticate products **8** for counterfeiting, fraud and tampering, as disclosed herein while simultaneously providing tenants with the features and benefits of RFID/RAINFC technology.

Additional embodiments and uses of the invention are now considered.

Bulk Encoding System for NFC/RFID Tags Using Reel-to-Reel Technology. As demonstrated herein, embodiments of the invention may comprise a bulk encoding process employing a proprietary reel-to-reel machine designed for encoding large quantities of NFC and RFID tags efficiently. The system leverages an advanced configuration that synchronizes each tag's positioning with an encoding terminal, ensuring precise alignment for data encoding and verification. Each tag is programmed with a unique identifier and an encrypted tap-unique URL **93**, which links to a secure database **302** and blockchain **322** containing product-specific data. In an embodiment, PCD encoding device (encoding terminal) **20** is functionally integrated within the system such that the tape passing from an origin reel to a capturing reel passes by, thereby encoding each tag affixed to the tape as it passes by PCD encoding device **20** in accordance with embodiments previously described. In embodiments, numerous tags **10** may be encoded per second. Upon completion of the bulk encoding process, the capturing reel of the tape, detachably attached to a spindle or other similar element for holding the reel, may be removed from the system machinery. With reference to the encoding interface of FIG. **14**, for example, batch encoding of 5,000 tags is in process using the batch encoding embodiment.

A key innovation in the reel-to-reel embodiment of the encoding system is the integration of KMS **342** for real-time encryption. Before encoding, in embodiments, API module **220** requests encryption key **99** from KMS **342** based on the tenant's specific encryption key ID **86**. The encryption process, as discussed with respect to embodiments in the disclosure, secures each tag **10** with tenant-specific credentials, thereby embedding a unique layer of security into every encoded tag **10**. Additionally, the reel-to-reel machine's process control system (in an embodiment, operating via encoding module **30** on local device **40**) verifies the encoded data on each tag before moving it to the next phase, ensuring high accuracy and preventing encoding errors. This approach reduces manual handling, accelerates production, and enhances the security and authenticity of each encoded tag **10** by securing encryption keys **99** directly at the point of encoding. With reference to FIG. **14**, for example, the encoding status of each tag **10** in the batch encoding process is listed as either "encoded" or "failed" (or other similar term in the event a particular tag **10** failed (for any reason) to be encoding during the encoding process.

Inventory Management and Product Authentication with Dual-Frequency Tags. Dual-frequency tags (NFC and radio frequency identification or RFID enabled) enable a sophisticated system for inventory management and product authentication by combining RFID and NFC technologies within a single tag. An example of a combined NFC/RFID enabled tag is EM4425 Tag, discussed above.

The configuration of a dual and combined NFC/RFID enabled tag may be designed for seamless integration into multi-layered supply chain and retail environments. For example, in embodiments, with a dual NFC/RFID enabled tag, through the RFID interface, inventory of products may be managed efficiently across large warehouses or retail

stores, with long-range reading capabilities that enable simultaneous scanning of multiple items, significantly reducing processing time.

For authentication, as demonstrated in embodiments throughout this disclosure, the NFC interface allows end-users **12** to tap tag **10** with PCD reading device **14** to access product information securely without the need for additional software such as an app. The tag's AES-128 encryption and optional digital signature support protect the encoded data, ensuring that each tag carries a verifiable authenticity marker. Another notable feature is the tag's tamper detection, as demonstrated above, which is designed to trigger an alert in response to a tap interaction if the tag has been physically compromised. This mechanism uses an impedance loop that signals a tampered state if broken. These tags may also include a shared memory accessible by both UHF and NFC interfaces, thereby allowing for streamlined data synchronization across inventory and authentication systems and simplifying the verification process for both consumer and backend systems.

Certificate Authority (CA) Account with Brand-Scoped Authentication and Tap Data Management. Embodiments of the invention may incorporate a centralized Certificate Authority ("CA") account that functions as a brand manager, overseeing the authentication process and tap data collection for multiple subordinate brands. When a tag **10** associated with a specific CA is tapped by end user **12**, the CA's logo and information are automatically displayed, providing an immediate visual confirmation of authenticity tied to the CA's identity. This tap interaction triggers a secure data request (as demonstrated in embodiments in the disclosure), wherein the tag's unique identifier, authentication details, and interaction metadata may be transmitted to the CA's secure database, creating a comprehensive log for each interaction. The transmittal of tap-interaction data **113** to the CA's secure database may be direct based on the tap-unique URL **93** or it may be accomplished from API module **220**. One of the proprietary elements of embodiments implementing this setup or configuration is the CA's role in isolating tap data strictly by brand. The CA system restricts data access, ensuring that only tap-interaction data **113** for the CA's registered products is accessible to them, while data from other brands remains confidential. This segmentation is achieved through encrypted URLs and blockchain-backed transaction logging, in accordance with disclosed embodiments, with each tap-interaction data **113** recorded to blockchain module **322** and generating unique blockchain transaction ID **97**. This immutable record, combined with tenant-specific encryption, allows the CA to audit its products' taps securely, providing real-time insights into product interactions and ensuring that only authorized brand representatives can access detailed tap histories.

Collecting Analytical Data on the Blockchain. Embodiments of the invention leverage blockchain technology not only for secure transactions and authentication but also for the collection of comprehensive analytical data. Each interaction with an NFC/RFID tag **10**, such as a tap or read event, generates a blockchain transaction that records detailed metadata **17** including timestamp, location, device type, and interaction context. This data, anonymized where necessary to protect consumer privacy, is stored immutably on blockchain module **322**, creating an auditable trail that can be analyzed to gain insights into consumer behavior, product performance, and supply chain efficiency.

The integration of blockchain analytics tools enables brands and supply chain managers to query and aggregate this transactional data securely. Advanced data analytics algorithms applied to the blockchain records can uncover patterns such as peak interaction times, regional product popularity, and potential bottlenecks in distribution. By correlating tap-interaction data with product lifecycles and market trends, businesses can make informed decisions on inventory management, marketing strategies, and product improvements. The decentralized and tamper-proof nature of the blockchain ensures the reliability and accuracy of these analytics, fostering trust and transparency in data-driven decision-making.

Moreover, tenant-specific permissions and encryption ensure that sensitive analytical data remains accessible only to authorized stakeholders. Brands can configure dashboards that pull real-time insights directly from blockchain module **322**, highlighting key performance indicators, consumer engagement metrics, and supply chain KPIs. This approach provides a secure, scalable, and transparent method for collecting and analyzing data across diverse products and markets without relying on centralized data repositories that may be vulnerable to breaches or manipulation.

Providing Warranties, Product Data, and Related Services. In addition to authentication and analytics, embodiments of the invention comprise the provision of warranties, detailed product data, and related services directly to consumers and stakeholders. When a consumer **12** interacts with a product tag **10** via an NFC-enabled device **14**, the tag **10** can deliver up-to-date warranty information, service guidelines, and product specifications. This information is securely linked through the tag's encrypted tap-unique URL **93** to a backend database (e.g., database module **302**) that holds comprehensive records, including warranty terms, manufacturing details, and maintenance history.

The use of blockchain module **322** enhances the integrity and verification of warranty claims and product data. For instance, a consumer **12** seeking to claim warranty service can initiate a verification process by tapping the tag, which triggers a secure transaction on the blockchain. The transaction confirms the product's authenticity, checks warranty status, and logs the claim request immutably. This process not only reduces fraud but also accelerates service response times by providing service centers with verified product and warranty information before the product arrives for repair or replacement.

Furthermore, tenants can update product data and warranty terms via secure blockchain transactions, ensuring that all stakeholders have access to the most current information. Manufacturers can publish updates, recalls, or service bulletins that are directly linked to the product's tag, allowing consumers to receive timely notifications and instructions.

Embodiments of the invention may incorporate mechanisms for collecting consumer data through interactive forms. For example, when a consumer **12** taps an NFC-enabled device **14** on a tagged product **8**, the system may prompt the user **12** with a secure digital form requesting voluntary contact and preference information such as email addresses, phone numbers for SMS, and social media profiles. These forms may be delivered directly to the consumer's smartphone or other devices **14**, leveraging secure web interfaces or native applications to capture data efficiently and in real time.

The secure collection of consumer data via these forms is integrated into the broader ecosystem of product interaction, ensuring that all submitted information is transmitted over encrypted channels and stored in compliance with data protection standards. In embodiments, API module **220** saves such information to database module **302** for further use and analysis as described herein. In embodiments, one or

more of such consumer data, such as, for example, warranty information, purchase date, repair date(s) and the like may be recorded on blockchain module **322**, thereby creating an immutable record of a consumer's history with unique product **8**. As consumers submit their details, the data is automatically linked to their interaction history with specific products through the embedded RAINFC tag, enhancing the personalization of marketing campaigns and loyalty programs. The process includes explicit consent options and transparency disclosures, adhering to privacy regulations and best practices by allowing consumers to opt-in for communications via email, SMS, or social media platforms.

In embodiments, collected consumer data may then be utilized for targeted marketing strategies, personalized offers, and improved customer service initiatives. For example, email and SMS campaigns tailored to individual consumer preferences may be generated based on the data provided, while social media integrations allow for seamless connection between brand engagements and consumers' digital profiles. This approach not only enriches the consumer experience but also empowers brands with valuable insights derived from aggregated and anonymized consumer data, facilitating more informed decision-making and fostering long-term customer relationships.

Other features and elements of embodiments are as follows:

Tenant-Specific Key Management and Tenant Functions. In addition to the administrative controls of API module **220**, each tenant using the methods, processes and systems of embodiments is provisioned with unique cryptographic key pairs, consisting of public and private keys. These tenant-specific keys empower tenants to interact with blockchain module **322** in a secure and decentralized manner. During the onboarding process, tenants receive their individual key pairs, which are securely stored and managed to ensure that only authorized tenants can access and utilize them. This key management strategy is fundamental to maintaining both security and accountability within the system. As such, according to embodiments, tenants are granted permission to access blockchain module **322** for transactions concerning their respective products **8**.

In embodiments, tenants may leverage their unique keys in accordance with the above to perform several critical functions:

Creating Tags. Tenants may create tags **10** that uniquely identify and categorize tap-transactions **113** and data entries on blockchain module **322**. Tags **10** are generated using the tenant's private key, ensuring that each tag is authentic and traceable back to its origin. This capability facilitates organized and efficient data management, allowing tenants to maintain clear and structured records within the blockchain.

Querying the Blockchain. Tenants are authorized to query blockchain module **220** to retrieve specific data or transaction histories recorded therein. These read operations are authenticated using the tenant's public key, ensuring that tenants can access only the data they are permitted to view. This selective access control preserves the confidentiality and integrity of the data while providing tenants with the necessary visibility to monitor and analyze their transactions on blockchain module **322**.

Posting Transactions. Tenants may submit their own transactions to the blockchain for processing. Each transaction is digitally signed with the tenant's private key, providing irrefutable proof of origin and ensuring that only legitimate transactions are recorded on the blockchain. Before a transaction is accepted and recorded in blockchain module **322**, in accordance with disclosed embodiments, the system verifies the digital signature against the tenant's public key, thereby validating the authenticity and authorization of the transaction. This rigorous validation process ensures that all transactions are legitimate and that the blockchain remains free from unauthorized or malicious entries.

While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised that do not depart from the scope of the invention as disclosed herein. The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, including various features and limitations of embodiments, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as may be suited to the particular use contemplated.

The process parameters and sequence of steps described and/or illustrated herein are given by way of example only. For example, while the steps illustrated and/or described herein may be shown or discussed in a particular order, these steps do not necessarily need to be performed in the order illustrated or discussed. Some of the steps may be performed simultaneously. For example, in certain circumstances, multitasking and parallel processing may be advantageous. The various example methods described and/or illustrated herein may also omit one or more of the steps described or illustrated herein or include additional steps in addition to those disclosed.

While the foregoing disclosure sets forth various embodiments using specific block diagrams, flowcharts, and examples, each block diagram component, flowchart step, operation, and/or component described and/or illustrated herein may be implemented, individually and/or collectively, using a wide range of hardware, software, or firmware (or any combination thereof) configurations. In addition, any disclosure of components contained within other components should be considered as examples because many other architectures can be implemented to achieve the same functionality.

For example, one or more of the software modules disclosed herein may be implemented in a cloud computing environment. Cloud computing environments may provide various services and applications via the Internet. These cloud-based services (e.g., software as a service, platform as a service, infrastructure as a service, etc.) may be accessible through a web browser or other remote interface.

One or more elements of the above-described systems and embodiments may be implemented using software modules that perform certain tasks. These software modules may include script, batch, or other executable files that may be stored on a computer-readable storage medium or in a computing system. These software modules may configure a computing system to perform one or more of the example embodiments disclosed herein. The computer readable program code may be stored, temporarily or permanently, on one or more non-transitory computer readable storage media. The non-transitory computer readable storage media are executable by one or more computer processors to perform the functionality of one or more components of the above-described systems (e.g., FIGS. **1**, **3** and **8**) and/or

flowcharts (e.g., FIGS. **7-8**). Computer storage media includes volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, hard drives, flash memory, solid state drives, random access memory (RAM), read only memory (ROM), electrically erasable programmable ROM (EEPROM), flash memory or other memory technology, compact disk ROM (CD-ROM), digital versatile disks (DVDs) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store the desired information and that can be accessed to retrieve that information.

Embodiments described herein may be discussed in the general context of computer-executable instructions residing on some form of computer-readable storage medium, such as program modules, executed by one or more computers or other devices. Generally, program modules include routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or distributed as desired in various embodiments.

Embodiments may be implemented on a specialized computer system. The specialized computing system may include one or more modified mobile devices (e.g., laptop computer, smart phone, personal digital assistant, tablet computer, or other mobile device), desktop computers, servers, blades in a server chassis, or any other type of computing device(s) that include at least the minimum processing power, memory, and input and output device(s) to perform one or more embodiments.

Servers depicted in embodiments generally represent computing devices or systems, such as application servers or database servers, configured to provide various database services and/or run certain software applications. A network featuring one or more servers, for example, the embodiment according to FIG. **1**, generally represents any telecommunication or computer network including, for example, an intranet, a wide area network (WAN), a local area network (LAN), a personal area network (PAN), or the Internet.

Although components of one or more systems disclosed herein may be depicted as being directly communicatively coupled to one another, this is not necessarily the case. For example, one or more of the components may be communicatively coupled via a distributed computing system, a cloud computing system, or a networked computer system communicating via the Internet.

With regard to various computer systems and schematics depicted herein, it should be appreciated that any one computer system may represent many computer systems, arranged in a central or distributed fashion. For example, such computer systems may be organized as a central cloud and/or may be distributed geographically or logically to edges of a system such as a content/data delivery network or other arrangement. It is understood that virtually any number of intermediary networking devices, such as switches, routers, servers, etc., may be used to facilitate communication.

Embodiments of the invention may be implemented on various mobile or non-mobile computing devices, regardless of the platform being used (collectively, mobile and non-mobile devices referred to as "computing devices"). In embodiments, PCD reading device **14**, for example, may comprise a mobile device, and in one or more embodiments of the invention, a mobile device may include any portable device that provides a user interface. Examples of mobile devices may include, but are not limited to, cellular phones, personal digital assistants, personal communicators, tablet computers, smartphones, or any other computing device. Computing devices may include one or more processors, memory (e.g., RAM, cache memory, flash memory, etc.), a storage device (e.g., a hard disk, a solid-state drive, an optical drive such as a compact disk drive or digital video disk (DVD) drive, a flash memory stick, etc.), a wireless interface, a network interface and numerous other elements and functionalities typical of computing devices.

Computing devices suitable for use with embodiments may include various input means and output means, such as a keyboard, a receiver, and/or a touch sensitive display device (e.g., a touch liquid crystal display screen), which permits a user (e.g., end user **12**) to perform gestures (e.g., drag, swipe, multi-touch, select, press and hold, etc.) and enter/display keystrokes (including numeric, alphabetic, and other characters, images, or other media types).

Computing devices may be connected to a network (e.g., a local area network (LAN), a wide area network (WAN) such as the Internet, or any other similar type of network) via an antenna, wireless interface, and/or network interface. In one or more embodiments of the invention, the network connection may be facilitated by a wireless infrastructure, including one or more transceivers cooperating to facilitate wireless communications to wireless devices. A wireless infrastructure may include one or more routers, switches, microwave links, base stations, optical fibers, or other similar networking hardware or software components.

In one or more embodiments of the invention, the network connection may be facilitated by a hardwired or other similar connection using a network interface. For example, the network connection may involve a hardwire connection or short-range wireless connectivity technology with a second mobile device. Hardwired infrastructure may include one or more routers, switches, microwave links, base stations, optical fibers, or other similar networking hardware or software components.

In the computing systems of embodiments, as depicted in FIG. **1**, for example, the computing system may include one or more computer processor(s), associated memory (e.g., random access memory (RAM), cache memory, flash memory, etc.), one or more storage device(s) (e.g., a hard disk, an optical drive such as a compact disk (CD) drive or digital versatile disk (DVD) drive, a flash memory stick, etc.), and numerous other elements and functionalities. The computer processor(s) may be an integrated circuit for processing instructions. For example, the computer processor(s) may be one or more cores or microcores of a processor. The computing system may also include one or more input device(s), such as a touchscreen, keyboard, mouse, microphone, touchpad, electronic pen, or any other type of input device. Further, the computing system may include one or more output device(s), such as a screen (e.g., a liquid crystal display (LCD), a plasma display, touchscreen, cathode ray tube (CRT) monitor, projector, or other display device), a printer, external storage, or any other output device. The computing system may be connected to a network (e.g., a local area network (LAN), a wide area network (WAN) such as the Internet, mobile network, or any other type of network) via a network interface connection. The input and output device(s) may be locally or remotely connected (e.g., via the network) to the computer processor(s), memory, and storage device(s).

A portion of the disclosure may contain material that is subject to copyright, trade dress and/or trademark protec-

tion. Any such material comprising this disclosure is the express intellectual property of its respective owner, and it is understood the owner thereof reserves any and all rights in and to its respective intellectual property.

What is claimed is:

1. A system for authenticating a product, comprising:

a computer processor, and

an API module executing on the computer processor and configured to enable the computer processor to:

generate a unique product identifier for the product,

generate a data structure for the product, wherein the data structure comprises the unique product identifier,

send a request to a blockchain module to record the data structure for the product,

whereupon receiving the request, the blockchain module records the data structure for the product on the blockchain module in an initial transaction, generates an initial blockchain transaction identifier for the initial transaction, and transmits to the API module the initial blockchain transaction identifier for the initial transaction in response to the request,

receive from the blockchain module the initial blockchain transaction identifier for the initial transaction,

add the initial blockchain transaction identifier for the initial transaction to the data structure for the product, thereby associating the initial blockchain transaction identifier with the unique product identifier,

encode a near field communication tag to be affixed to the product with an initial tap-unique URL wherein the initial tap-unique URL comprises the unique product identifier,

whereupon, when the tag affixed to the product engages in a tap interaction with a proximity coupling device,

the tag generates a subsequent tap-unique URL on the tag, wherein the subsequent tap-unique URL comprises the unique product identifier, and

a web client operating on the proximity coupling device reads and opens the subsequent tap-unique URL,

receive from the web client the unique product identifier and a one or more tap interaction data generated from the tap interaction,

identify the initial blockchain transaction identifier associated with the unique product identifier received from the web client,

whereupon, based on the initial blockchain transaction identifier, send a subsequent request to the blockchain module to record the one or more tap interaction data generated from the tap interaction, and

whereupon receiving the subsequent request, the blockchain module records the one or more tap interaction data on the blockchain module in a subsequent transaction, generates a subsequent blockchain transaction identifier for the subsequent transaction, and transmits to the API module the subsequent blockchain transaction identifier for the subsequent transaction in response to the request,

receive from the blockchain module the subsequent blockchain transaction identifier for the subsequent transaction, and

add the subsequent blockchain transaction identifier for the subsequent transaction to the data structure for the product, thereby associating the subsequent blockchain transaction identifier with the unique product identifier.

2. The system of claim **1**, wherein the steps commencing with the tap interaction are repeated one or more times, resulting in one or more subsequent transactions on the blockchain module and one or more subsequent blockchain transaction identifiers, and wherein the initial blockchain transaction identifier as recited therein comprises a previous most recent subsequent blockchain transaction identifier.

3. The system of claim **2**, wherein the subsequent tap-unique URL further comprises a web host portion, a tag data, and an initial cryptographic output data.

4. The system of claim **3**, wherein the tag data is encrypted.

5. The system of claim **3**, wherein the initial cryptographic output data comprises a one-time password, a digital signature, or a message authentication code.

6. The system of claim **5**, wherein the API module is further configured to enable the computer processor to verify an authenticity of the product.

7. The system of claim **6**, wherein to verify the authenticity of the product, the API module is further configured to enable the computer processor to:

read the initial cryptographic output data from the subsequent tap-unique URL,

decrypt the encrypted tag data of the subsequent tap-unique URL using an encryption key associated with the product to generate a decrypted tag data,

generate a subsequent cryptographic output data using the decrypted tag data, a cryptographic algorithm, and the encryption key,

validate the subsequent cryptographic output data by comparing it against the initial cryptographic output data,

determine a verification result, wherein, if the subsequent cryptographic output data is validated, the verification result is that the product is authentic, and

transmit the verification result to the proximity coupling device to be viewed by a user.

8. The system of claim **7**, wherein the one or more tap interaction data sent to the blockchain module for recording in the subsequent transaction comprises the verification result.

9. The system of claim **7**, wherein the subsequent cryptographic output data comprises a one-time password, a digital signature, or a message authentication code.

10. The system of claim **3**, wherein the tag data comprises a one or more of the following: a unique tag identifier, an interaction counter data and a tag tamper detection data.

11. The system of claim **8**, wherein the one or more tap interaction data sent to the blockchain module for recording in the subsequent transaction further comprises a one or more of the following: the encrypted tag data, the initial cryptographic output data, the subsequent cryptographic output data, a geolocation of the proximity coupling device, an IP address of the proximity coupling device, a tap-unique identifier generated in response to the tap interaction, a one or more product code, an encoding date of the tag, a name of the product, a name of a tenant of the product, and a one or more meta data generated by the web client.

12. The system of claim **11**, wherein the one or more tap interaction data sent to the blockchain module for recording in the subsequent transaction further comprises one or more

of the following: the unique tag identifier, the interaction counter data, and the tag tamper detection data.

13. The system of claim **11**, wherein the one or more product code comprises a UPC code, a bar code, a product serial number, a QR code, an EPC code, a GS1 DataMatrix code, a GS1 DataBar code, a Code 128 code, and a European Article Number code.

14. The system of claim **7**, wherein the API module is further configured to enable the computer processor to:

generate a downloadable verification certificate, and

transmit the downloadable verification certificate to the proximity coupling device.

15. The system of claim **7**, wherein the API module is further configured to enable the computer processor to add the verification result to the data structure for the product.

16. The system of claim **1**, wherein the blockchain module is fee-less.

17. The system of claim **1**, wherein the tag is a dual NFC/RFID tag.

18. The system of claim **16**, wherein the blockchain module is Hyperledger.

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