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(54) RECORD-LEVEL ENCRYPTION SCHEME FOR DATA OWNERSHIP PLATFORM

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(22) Filed: **Jun. 28, 2024**

(51) **Int. Cl.**
H04L 9/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 9/088*** (2013.01)

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

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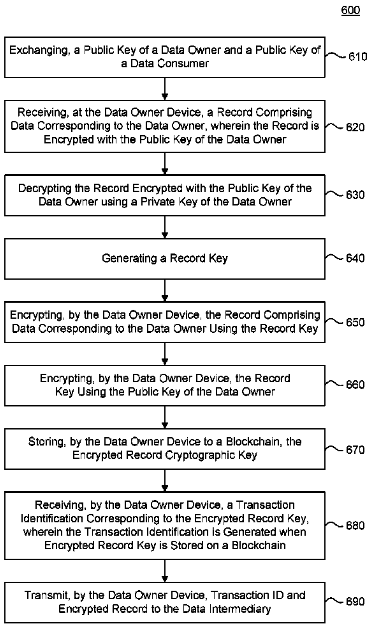
(57) **ABSTRACT**

Disclosed herein are embodiments for a record-level encryption scheme. A data visibility control platform may facilitate record-level encryption between a data owner device and a requester device, requesting access to the encrypted record. The record may contain sensitive and/or confidential information of the data owner. The data owner may directly control the visibility of the record via the data visibility control platform. The data visibility control platform may use a combination of private and public cryptographic keys associated with the data owner and requester to provide record-level encryption. An embodiment may include record keys used to encrypt records being stored by a records database managed by a data intermediary. The record key may be encrypted using the public key of the data owner and stored on a blockchain. Access to the record key stored on the blockchain is controlled by the data owner.

24 Claims, 15 Drawing Sheets


600
Exchanging, a Public Key of a Data Owner and a Public Key of a Data Consumer
610
Receiving, at the Data Owner Device, a Record Comprising Data Corresponding to the Data Owner, wherein the Record is Encrypted with the Public Key of the Data Owner
620
Decrypting the Record Encrypted with the Public Key of the Data Owner using a Private Key of the Data Owner
630
Generating a Record Key
640
Encrypting, by the Data Owner Device, the Record Comprising Data Corresponding to the Data Owner Using the Record Key
650
Encrypting, by the Data Owner Device, the Record Key Using the Public Key of the Data Owner
660
Storing, by the Data Owner Device to a Blockchain, the Encrypted Record Cryptographic Key
670
Receiving, by the Data Owner Device, a Transaction Identification Corresponding to the Encrypted Record Key, wherein the Transaction Identification is Generated when Encrypted Record Key is Stored on a Blockchain
680
Transmit, by the Data Owner Device, Transaction ID and Encrypted Record to the Data Intermediary
690

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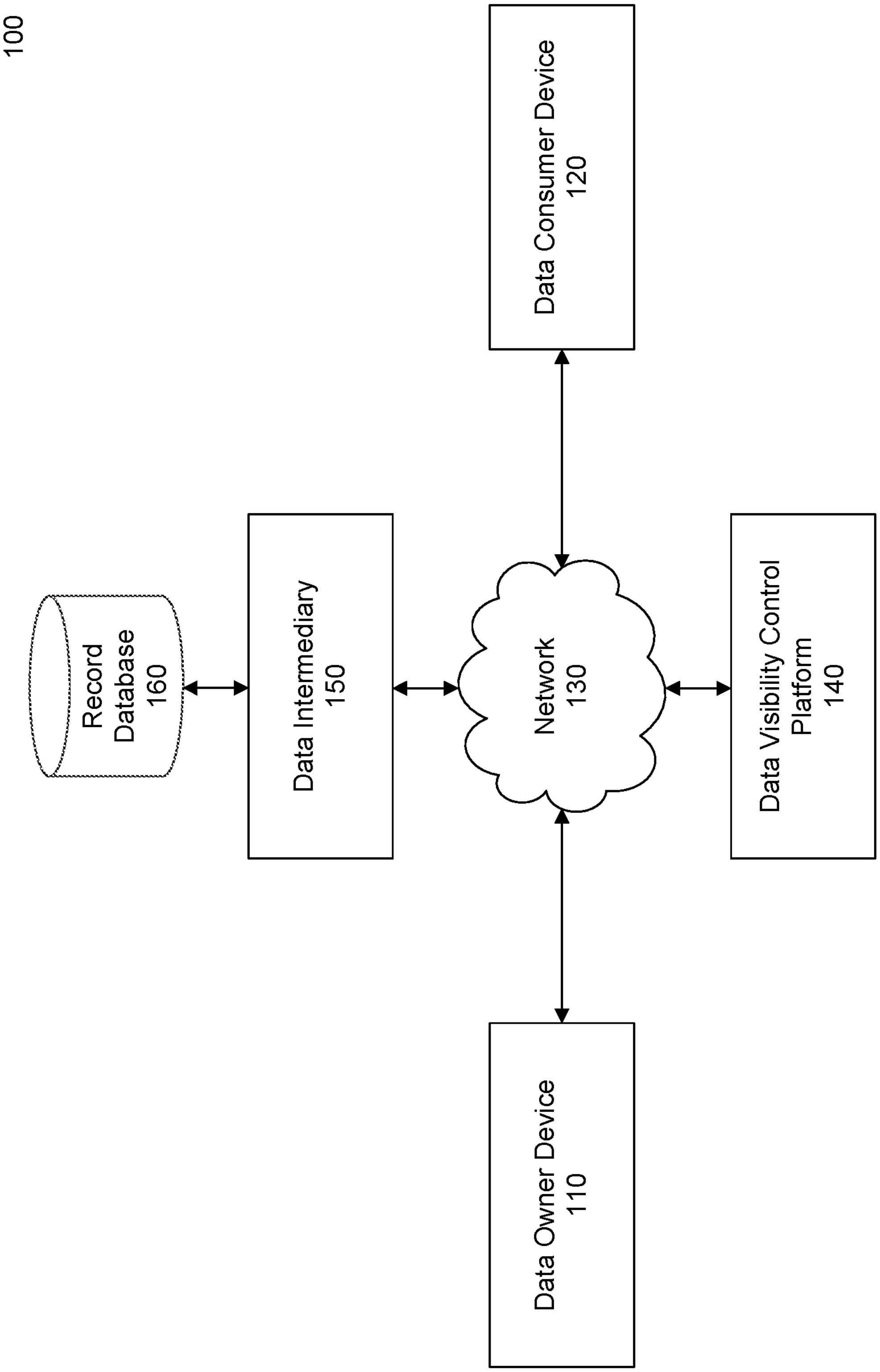

100
Data Consumer Device 120
Record Database 160
Data Intermediary 150
Network 130
Data Visibility Control Platform 140
Data Owner Device 110

FIG. 1A

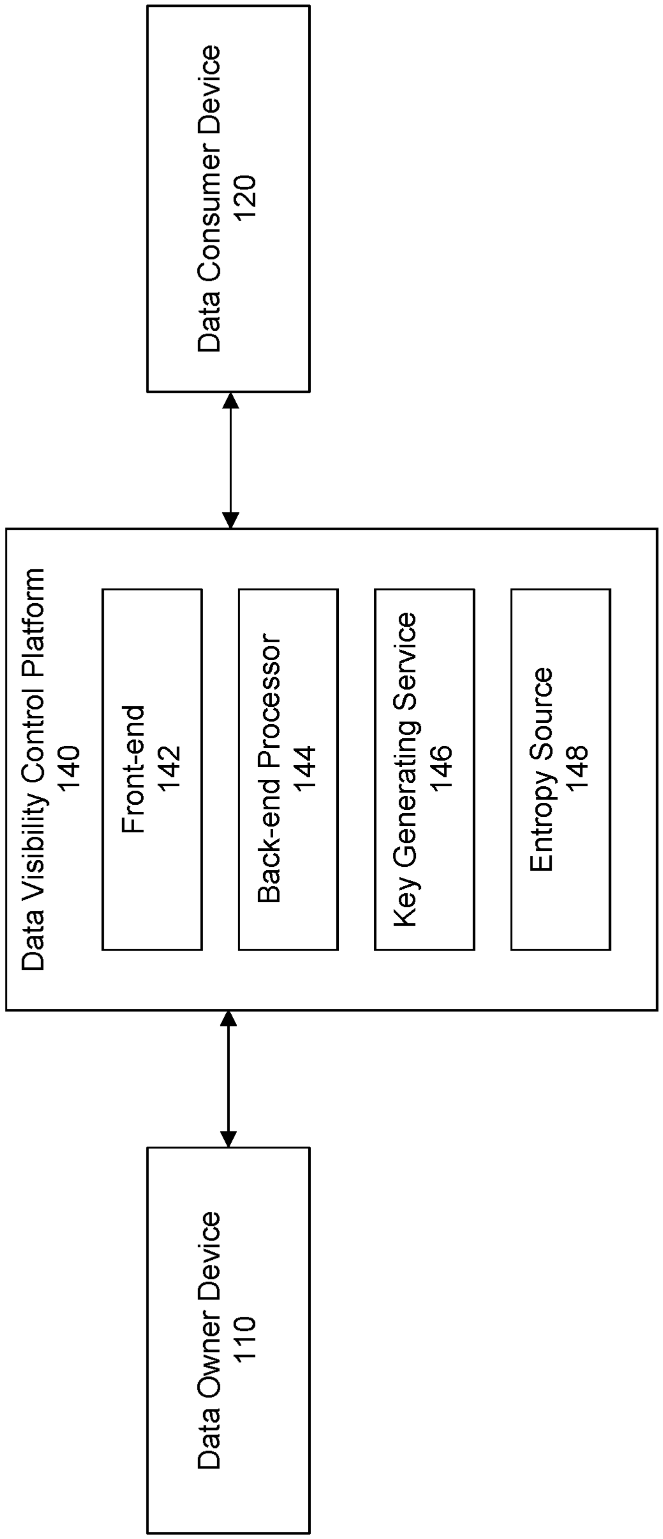

Data Consumer Device
120
Data Visibility Control Platform
140
Front-end
142
Back-end Processor
144
Key Generating Service
146
Entropy Source
148
Data Owner Device
110

FIG. 1B

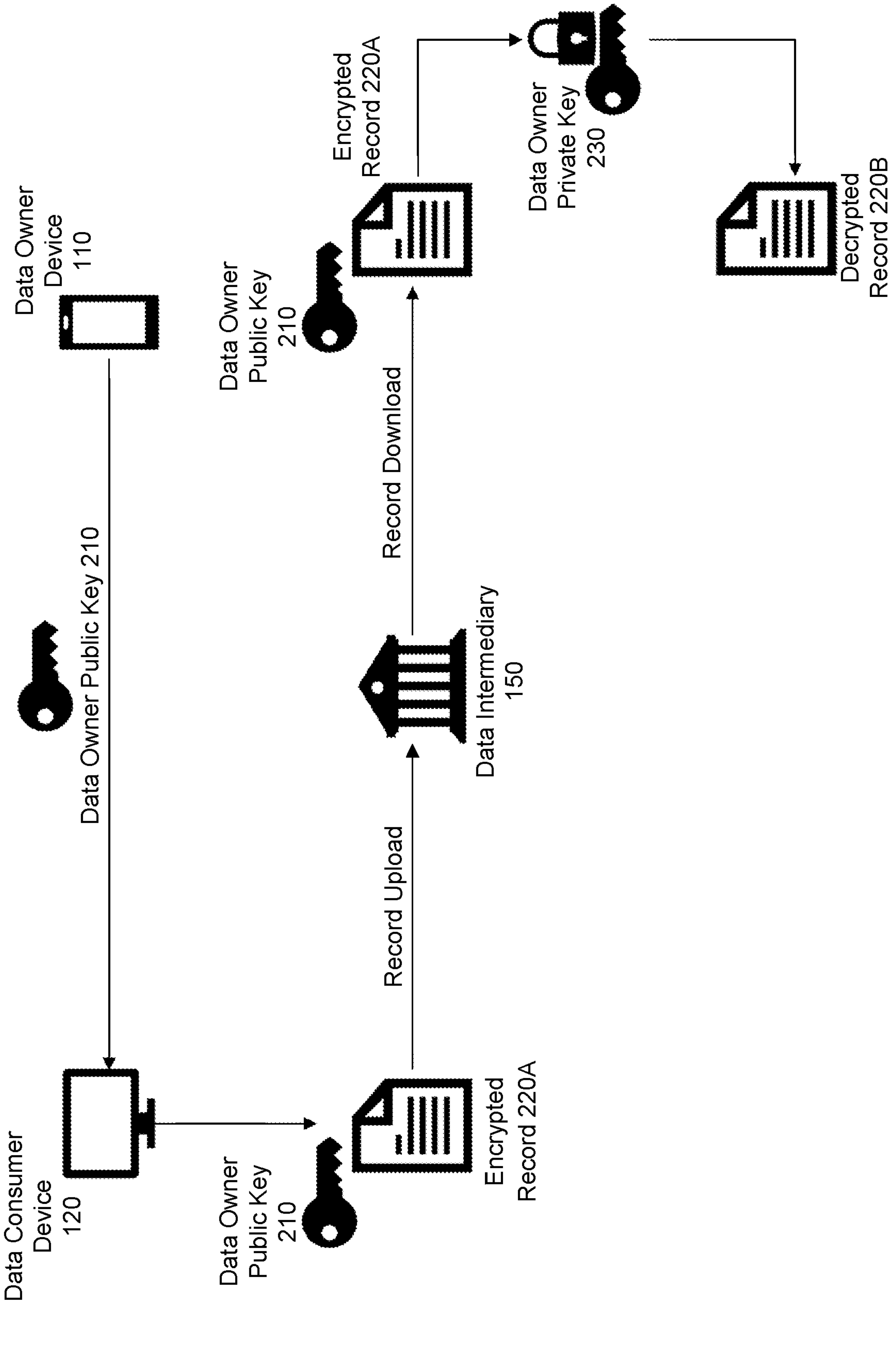

Data Consumer Device 120
Data Owner Public Key 210
Data Owner Device 110
Data Owner Public Key 210
Encrypted Record 220A
Record Upload
Data Intermediary 150
Record Download
Data Owner Public Key 210
Encrypted Record 220A
Data Owner Private Key 230
Decrypted Record 220B

FIG. 2A

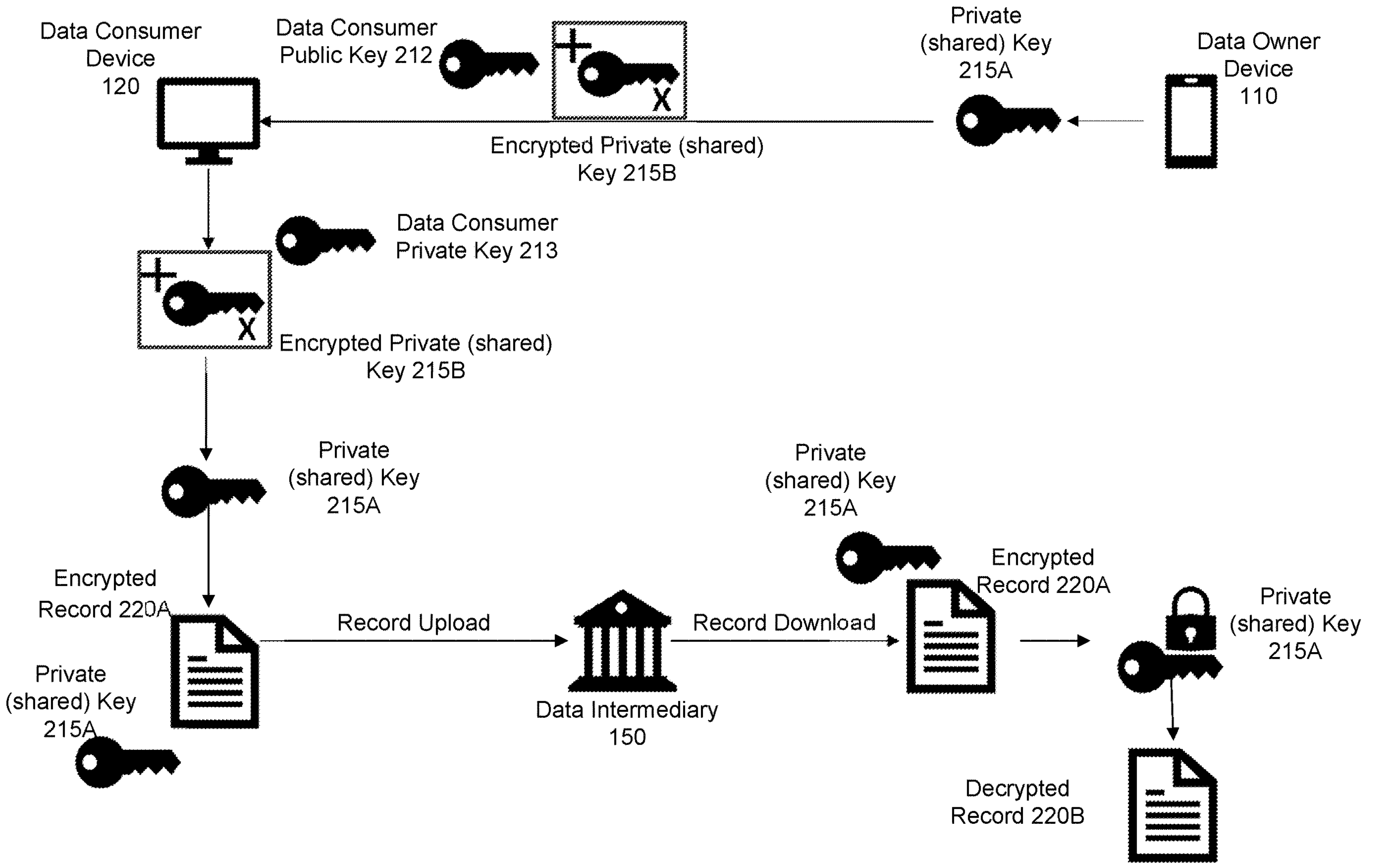

Data Consumer Device 120
Data Consumer Public Key 212
Private (shared) Key 215A
Data Owner Device 110
Encrypted Private (shared) Key 215B
Data Consumer Private Key 213
Encrypted Private (shared) Key 215B
Private (shared) Key 215A
Private (shared) Key 215A
Encrypted Record 220A
Encrypted Record 220A
Private (shared) Key 215A
Record Upload
Data Intermediary 150
Record Download
Private (shared) Key 215A
Decrypted Record 220B
Private (shared) Key 215A

FIG. 2B

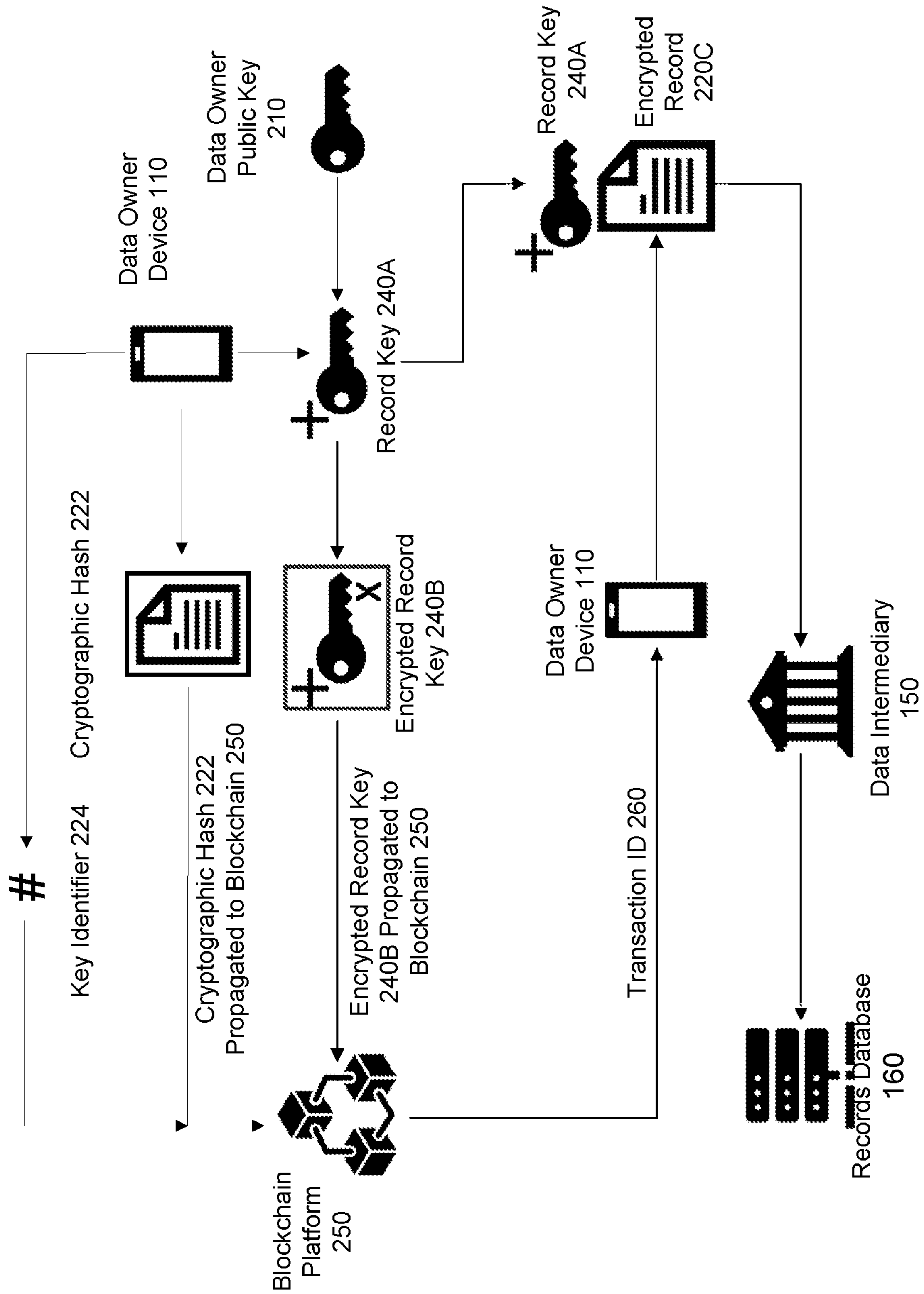
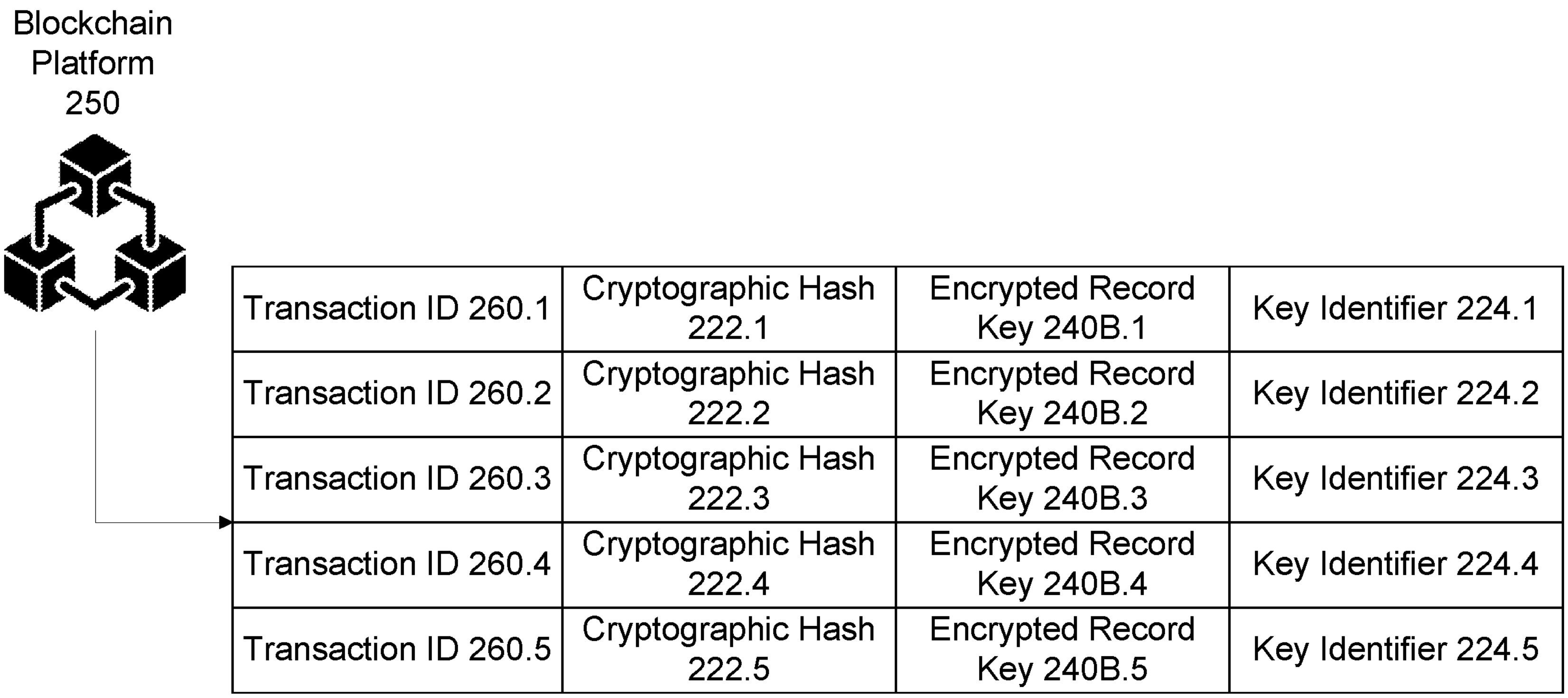
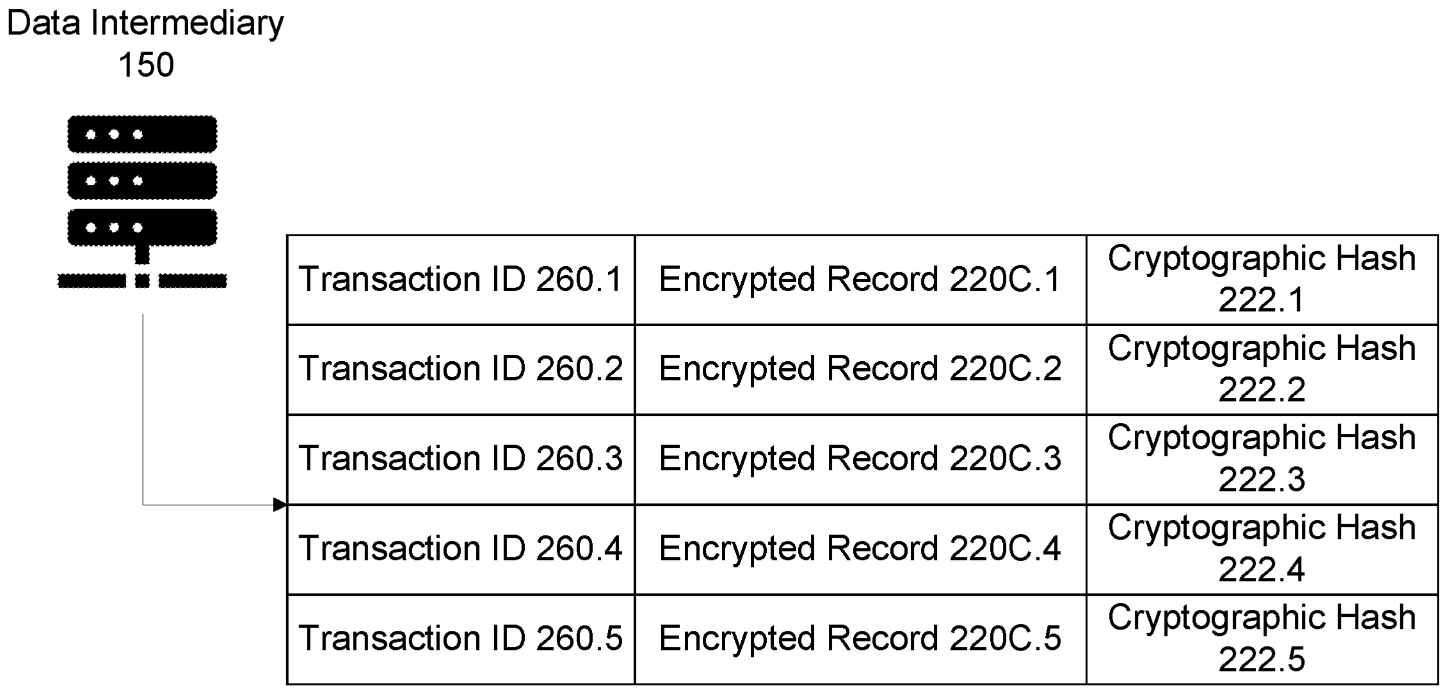

Data Owner Device 110
Data Owner Public Key 210
Record Key 240A
Encrypted Record 220C
Record Key 240A
Cryptographic Hash 222
Key Identifier 224
Encrypted Record Key 240B
Data Owner Device 110
Cryptographic Hash 222 Propagated to Blockchain 250
Encrypted Record Key 240B Propagated to Blockchain 250
Transaction ID 260
Data Intermediary 150
Blockchain Platform 250
Records Database 160

FIG. 2C



Transaction ID 260.1	Cryptographic Hash 222.1	Encrypted Record Key 240B.1	Key Identifier 224.1
Transaction ID 260.2	Cryptographic Hash 222.2	Encrypted Record Key 240B.2	Key Identifier 224.2
Transaction ID 260.3	Cryptographic Hash 222.3	Encrypted Record Key 240B.3	Key Identifier 224.3
Transaction ID 260.4	Cryptographic Hash 222.4	Encrypted Record Key 240B.4	Key Identifier 224.4
Transaction ID 260.5	Cryptographic Hash 222.5	Encrypted Record Key 240B.5	Key Identifier 224.5

FIG. 3A



Transaction ID 260.1	Encrypted Record 220C.1	Cryptographic Hash 222.1
Transaction ID 260.2	Encrypted Record 220C.2	Cryptographic Hash 222.2
Transaction ID 260.3	Encrypted Record 220C.3	Cryptographic Hash 222.3
Transaction ID 260.4	Encrypted Record 220C.4	Cryptographic Hash 222.4
Transaction ID 260.5	Encrypted Record 220C.5	Cryptographic Hash 222.5

FIG. 3B

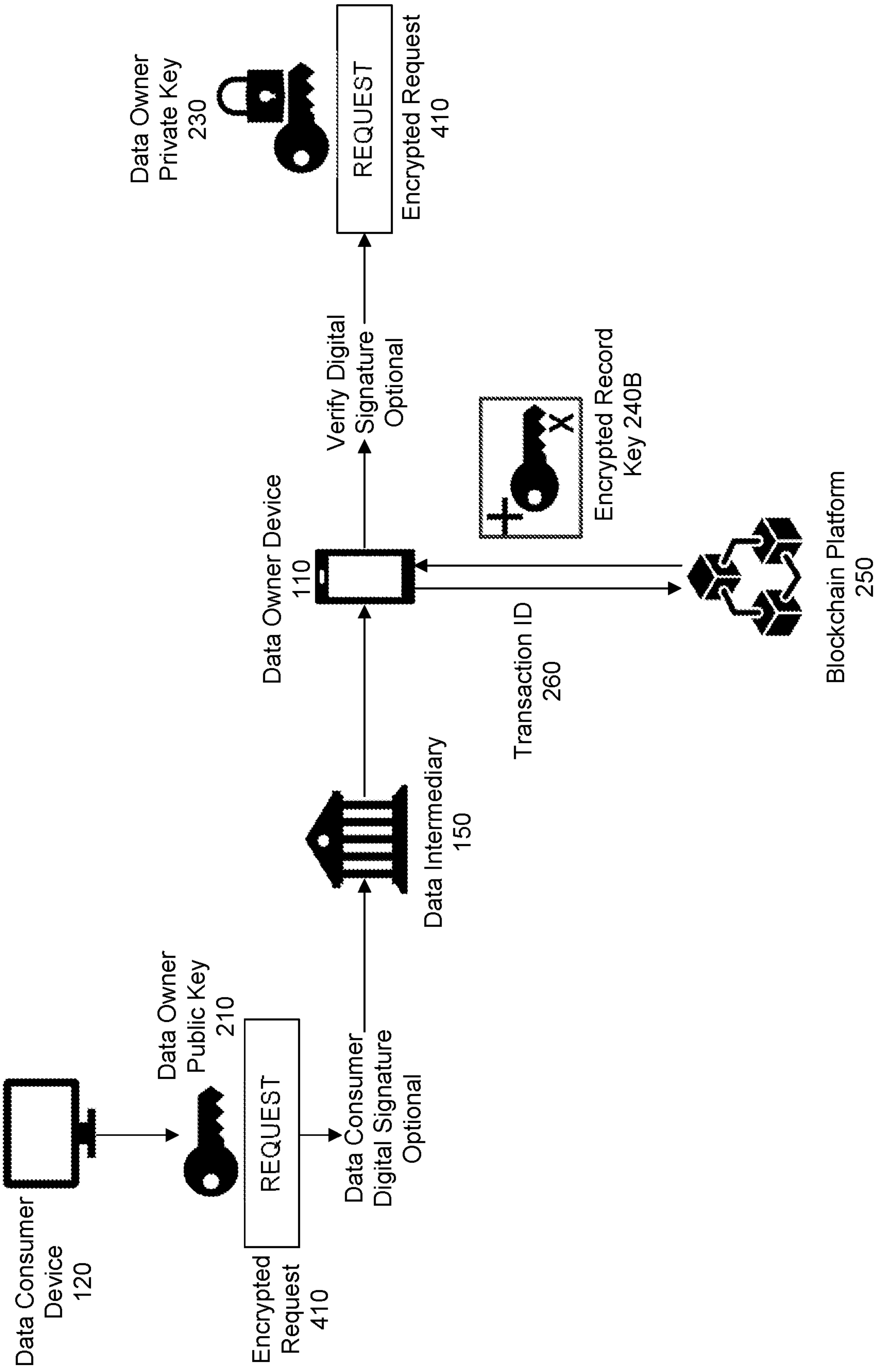

Data Consumer Device 120
Data Owner Public Key 210
REQUEST
Encrypted Request 410
Data Consumer Digital Signature Optional
Data Intermediary 150
Data Owner Device 110
Transaction ID 260
Blockchain Platform 250
Encrypted Record Key 240B
Verify Digital Signature Optional
Data Owner Private Key 230
REQUEST
Encrypted Request 410

FIG. 4A

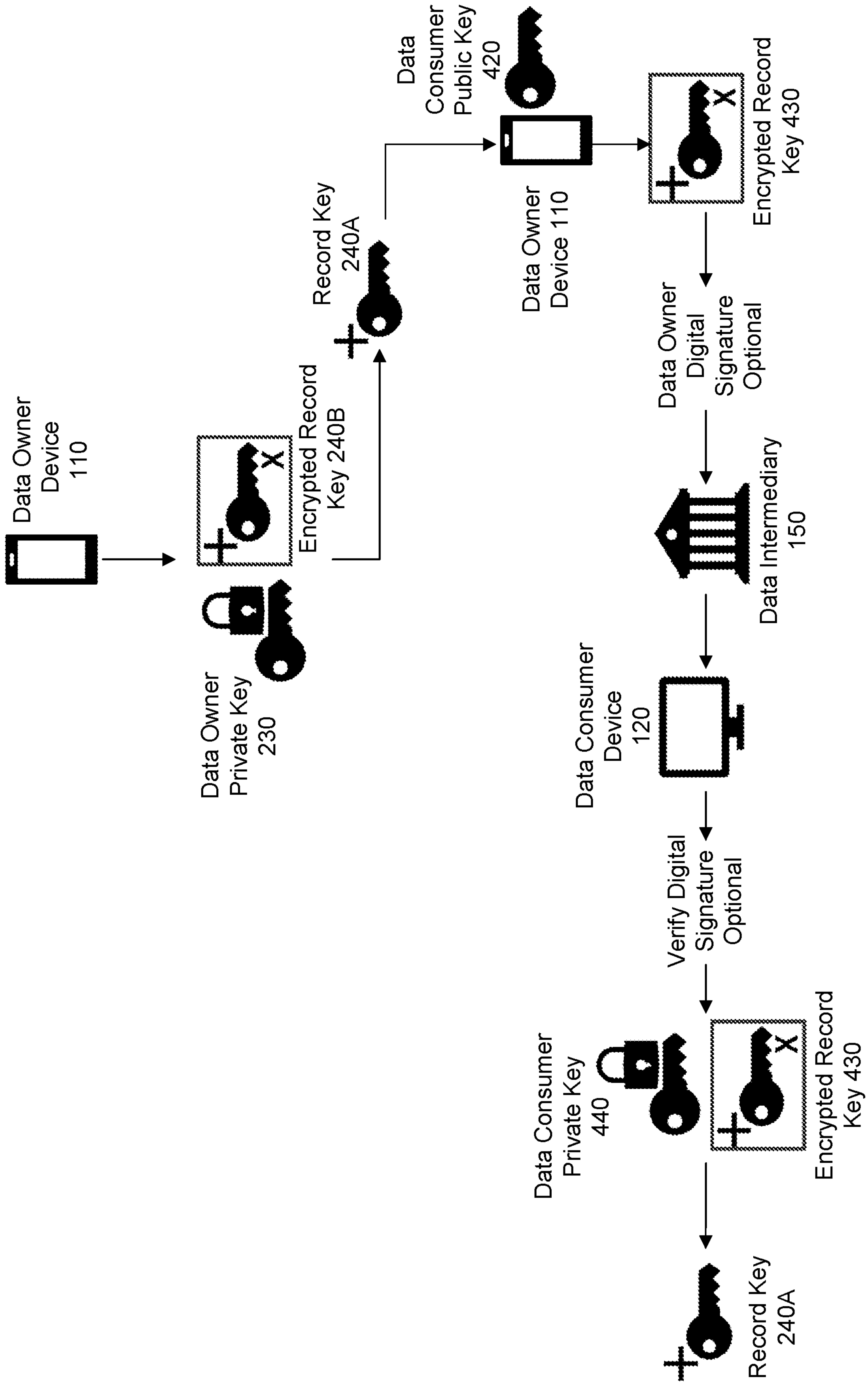

Data Owner Device 110
Data Owner Private Key 230
Encrypted Record Key 240B
Record Key 240A
Data Owner Device 110
Data Consumer Public Key 420
Encrypted Record Key 430
Data Owner Digital Signature Optional
Data Intermediary 150
Data Consumer Device 120
Verify Digital Signature Optional
Data Consumer Private Key 440
Encrypted Record Key 430
Record Key 240A

FIG. 4B

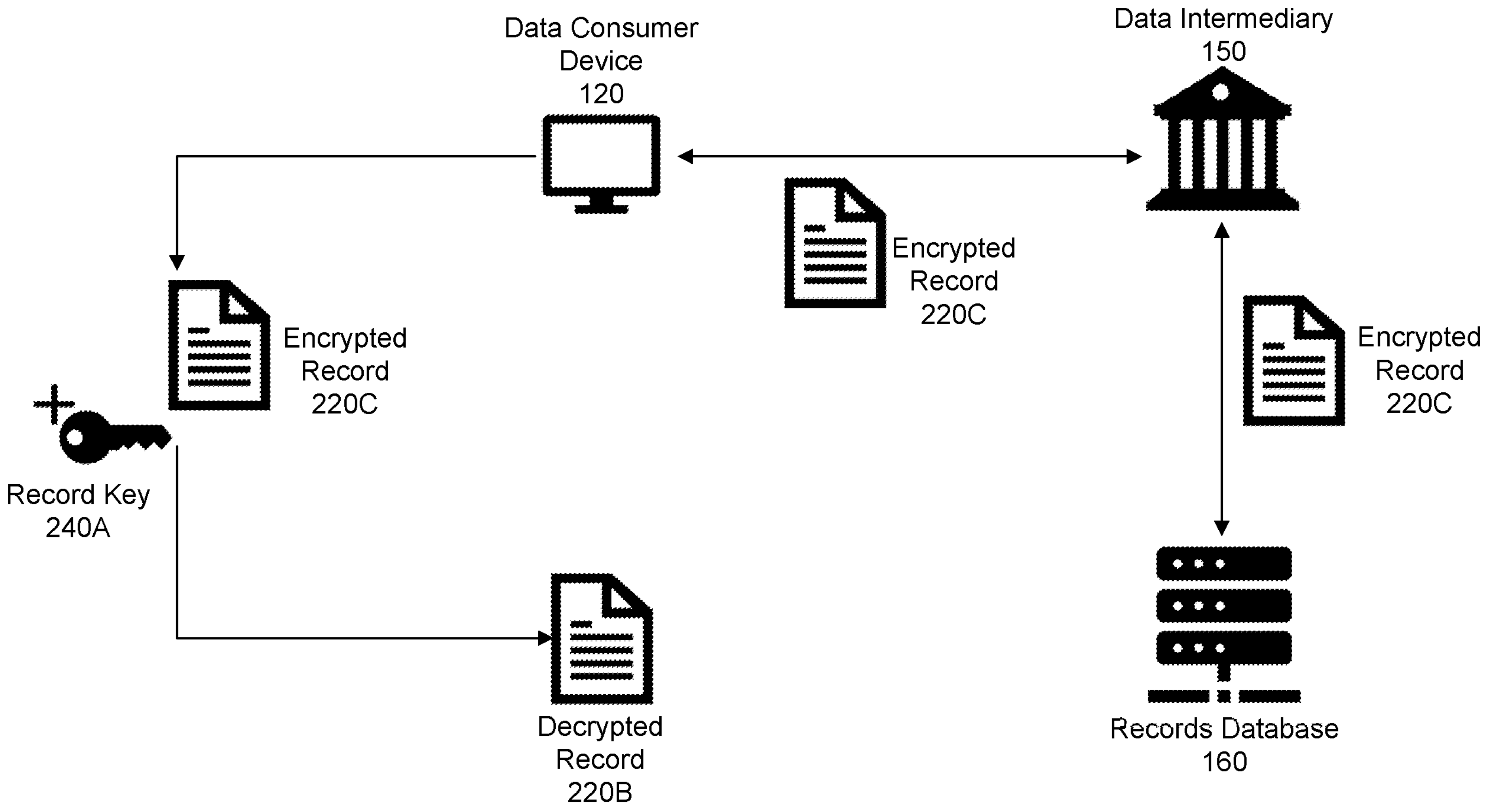

Data Consumer Device 120
Data Intermediary 150
Encrypted Record 220C
Encrypted Record 220C
Encrypted Record 220C
Record Key 240A
Decrypted Record 220B
Records Database 160

FIG. 4C

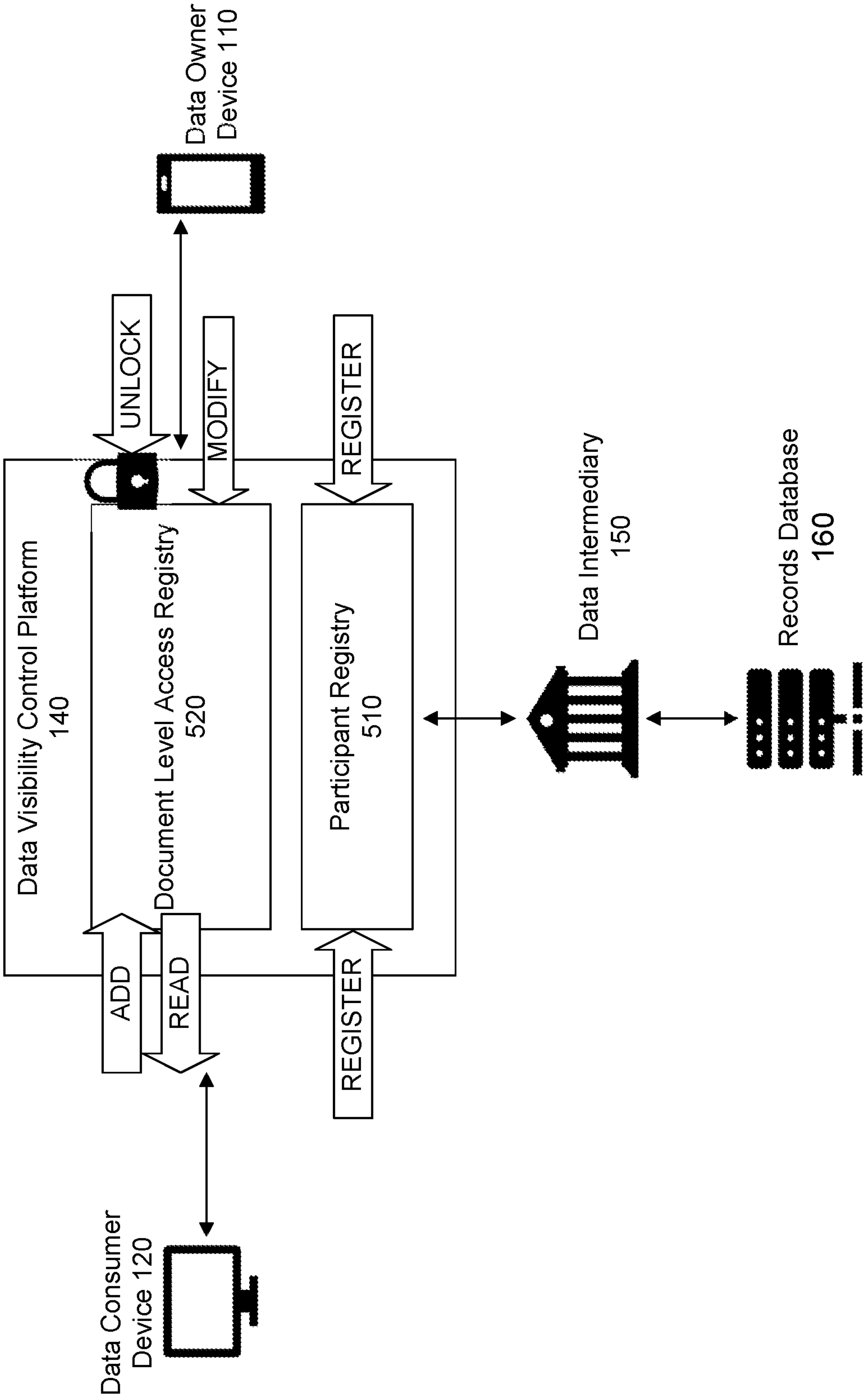

Data Visibility Control Platform
140
Document Level Access Registry
520
Participant Registry
510
UNLOCK
MODIFY
REGISTER
ADD
READ
REGISTER
Data Owner
Device 110
Data Consumer
Device 120
Data Intermediary
150
Records Database
160

FIG. 5

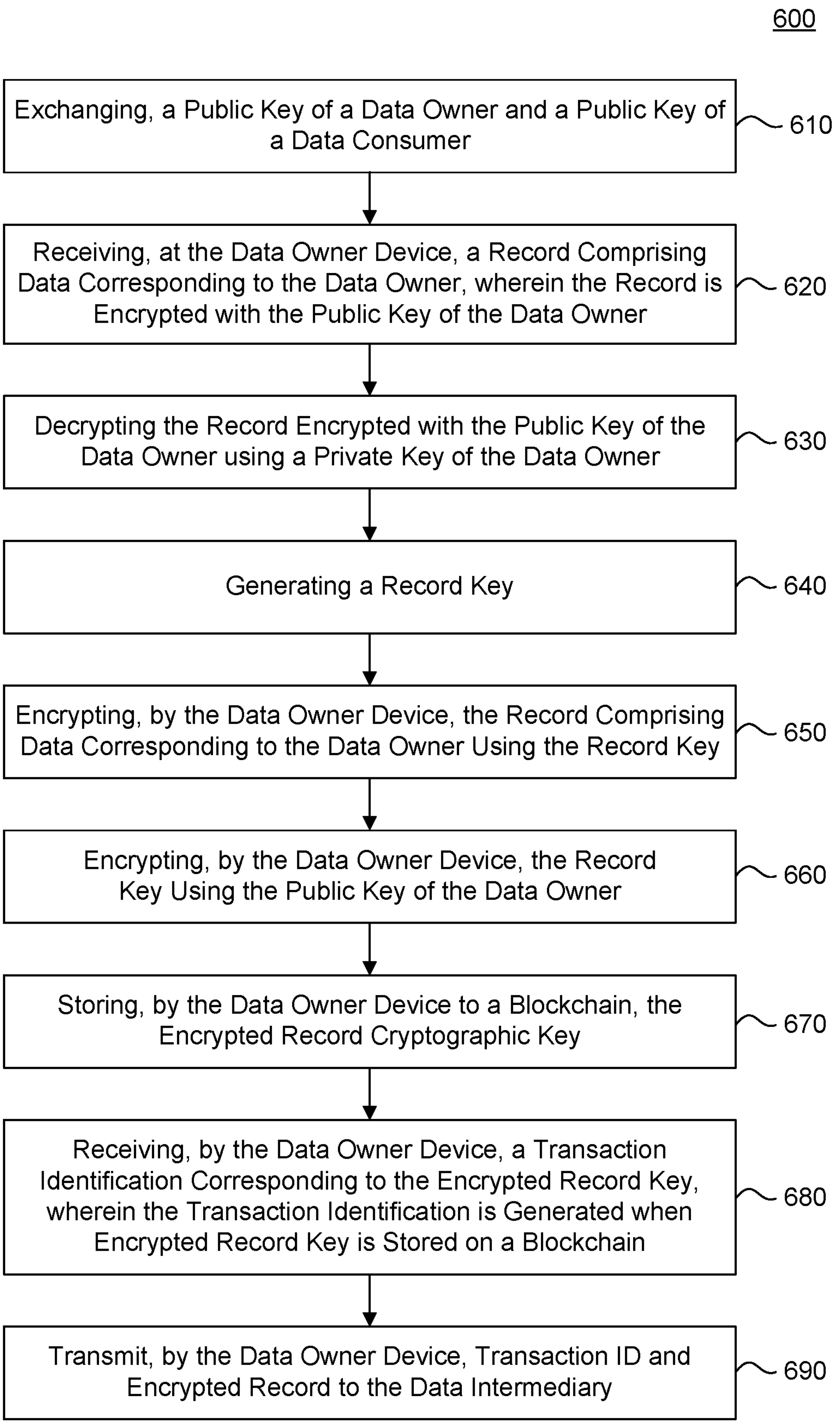

600
Exchanging, a Public Key of a Data Owner and a Public Key of a Data Consumer
610
Receiving, at the Data Owner Device, a Record Comprising Data Corresponding to the Data Owner, wherein the Record is Encrypted with the Public Key of the Data Owner
620
Decrypting the Record Encrypted with the Public Key of the Data Owner using a Private Key of the Data Owner
630
Generating a Record Key
640
Encrypting, by the Data Owner Device, the Record Comprising Data Corresponding to the Data Owner Using the Record Key
650
Encrypting, by the Data Owner Device, the Record Key Using the Public Key of the Data Owner
660
Storing, by the Data Owner Device to a Blockchain, the Encrypted Record Cryptographic Key
670
Receiving, by the Data Owner Device, a Transaction Identification Corresponding to the Encrypted Record Key, wherein the Transaction Identification is Generated when Encrypted Record Key is Stored on a Blockchain
680
Transmit, by the Data Owner Device, Transaction ID and Encrypted Record to the Data Intermediary
690

FIG. 6A

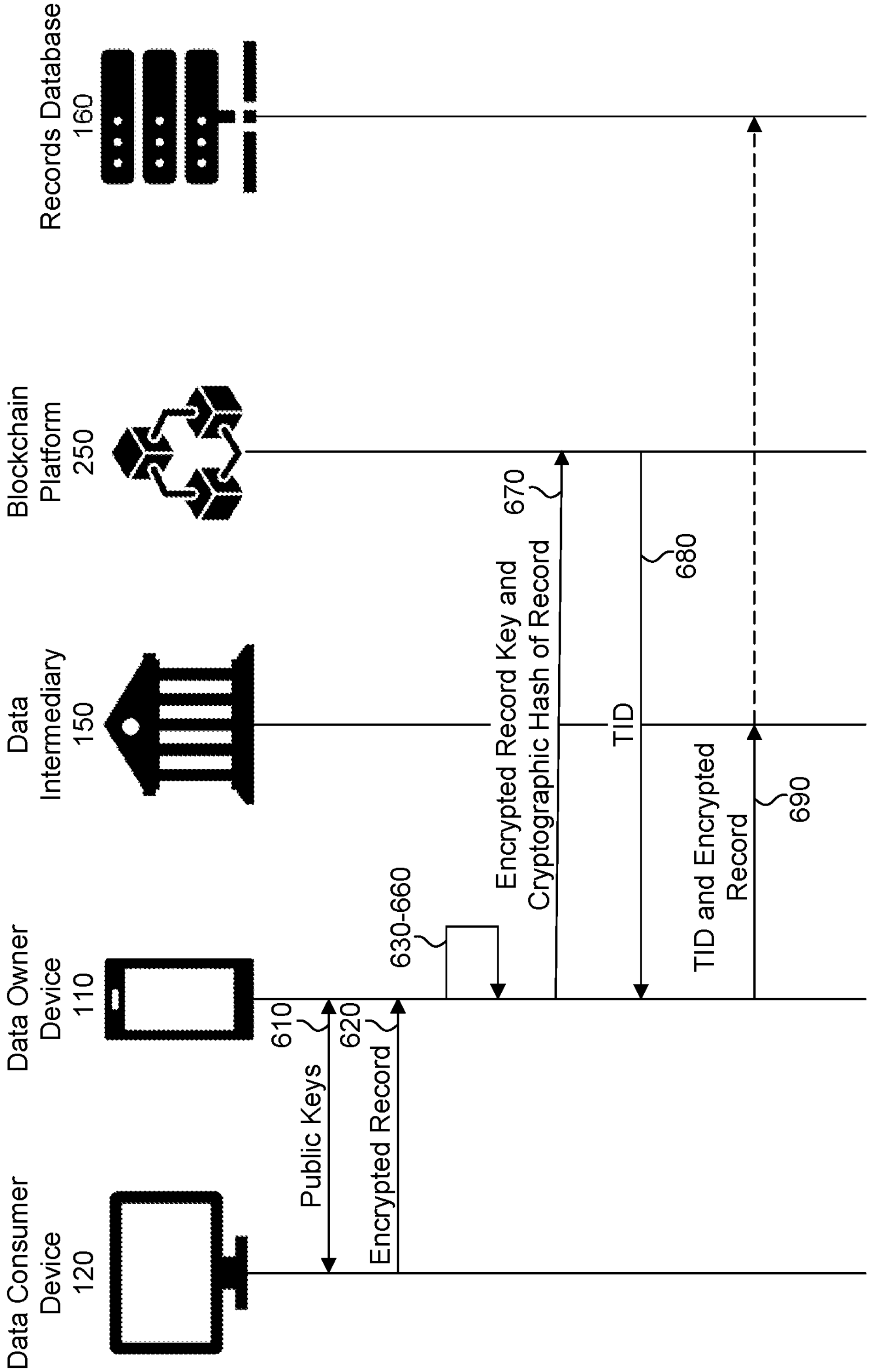

Data Consumer Device 120
Data Owner Device 110
Data Intermediary 150
Blockchain Platform 250
Records Database 160
Public Keys
610
Encrypted Record
620
630-660
Encrypted Record Key and Cryptographic Hash of Record
670
TID
680
TID and Encrypted Record
690

FIG. 6B

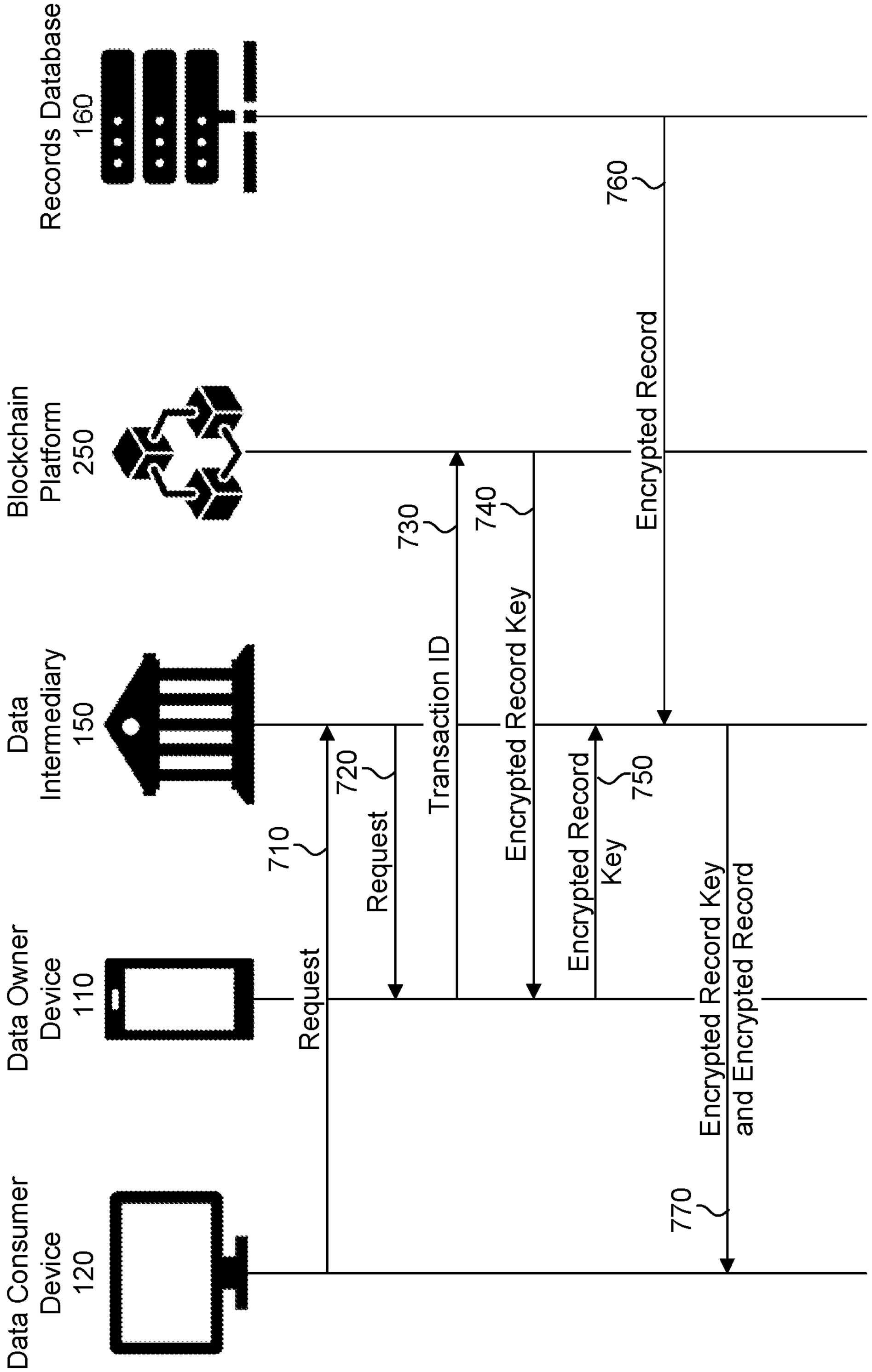

Data Consumer Device 120
Data Owner Device 110
Data Intermediary 150
Blockchain Platform 250
Records Database 160
710
Request
720
Request
730
Transaction ID
740
Encrypted Record Key
750
Encrypted Record Key
760
Encrypted Record
770
Encrypted Record Key and Encrypted Record

FIG. 7

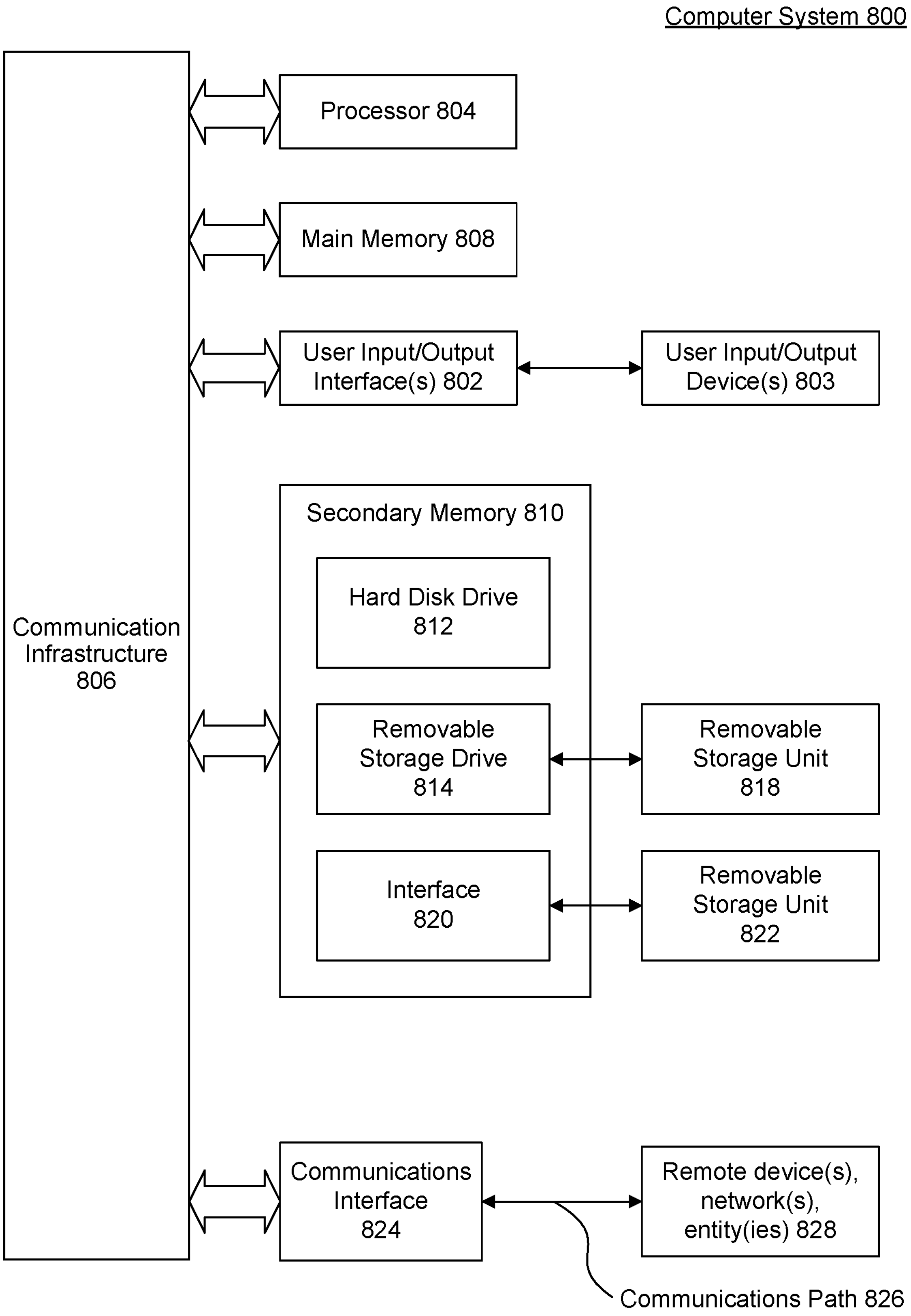

Computer System 800
Communication Infrastructure 806
Processor 804
Main Memory 808
User Input/Output Interface(s) 802
User Input/Output Device(s) 803
Secondary Memory 810
Hard Disk Drive 812
Removable Storage Drive 814
Removable Storage Unit 818
Interface 820
Removable Storage Unit 822
Communications Interface 824
Remote device(s), network(s), entity(ies) 828
Communications Path 826

FIG. 8

RECORD-LEVEL ENCRYPTION SCHEME FOR DATA OWNERSHIP PLATFORM

BACKGROUND

Field

The disclosed technology is generally related to systems and methods for a record-level encryption scheme for a data ownership platform.

Related Art

Consent management and data visibility are continuing issues as entities continue to electronically store and share data. Consent management may include access controls, e.g., enforcement of security protocols, as well as liability, e.g., liability for data breaches. Data visibility may include management of individuals and entities able to view, read, write, and edit stored data. In current systems, data consent management and visibility are centralized such that a data intermediary may manage both consent and visibility of the data of data owners for both data owners and data users.

In the healthcare industry, there have been efforts to allow patients to control their clinical data that have focused on the development of patient-managed records, or Personal Health Records (PHRs). These solutions, however, have significant shortcomings, such as placing significant administrative and security burdens on patients. Other known solutions for managing patient health records place control of record access with Data Intermediation Services Providers, and are used in combination with centralized clinical data repositories often referred to as Electronic Health Records (EHRs). EHRs offer certain advantages over PHRs, such as comprehensive health data, potential interoperability across systems, adherence to security and compliance standards, integration with clinical workflows, support for population health management, and facilitation of provider-to-provider communication. A clear disadvantage of current records access control methods applied to EHRs, however, is that patients do not control who has access to and visibility over their own data. The Data Intermediation Services Providers have both control over EHRs access and over the visibility of records maintained in the EHR. Currently, there is no solution that enables patients to control dissemination and use of their sensitive data while leveraging certain advantages that are associated with centralized data repositories such as EHRs.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are incorporated herein and form a part of the specification.

FIG. **1A-1B** depicts a block diagram of a record-level encryption environment, according to some embodiments.

FIGS. **2A-2B** depict example processes for providing record-level encryption for a newly generated record, according to some embodiments.

FIG. **2C** depicts an example process for storing an encrypted record in a records database using a record-level encryption scheme.

FIG. **3A** depicts an example record stored on a blockchain, according to some embodiments.

FIG. **3B** depicts example storage a plurality of transaction IDs for records associated with a data owner, according to some embodiments.

FIGS. **4A-4C** depict an example process for providing requester access to read a record stored with record-level encryption, according to some embodiments.

FIG. **5** depicts an example framework for data owner and requester registration for a record-level encryption scheme, according to some embodiments.

FIG. **6A-6B** depict a flowchart illustrating a method for generating and storing a record, according to some embodiments.

FIG. **7** is a process flow diagram illustrating a process for accessing a record, according to some embodiments.

FIG. **8** is a block diagram of an example computer system useful for implementing various embodiments.

In the drawings, like reference numbers generally indicate identical or similar elements. Additionally, generally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

Provided herein are system, apparatus, device, method and/or computer-program product (non-transitory computer-readable storage medium or device) embodiments, and/or combinations and sub-combinations thereof, for a record-level encryption scheme for a data-ownership platform.

Disclosed herein are systems and methods for a record-level encryption scheme that decentralizes data visibility control, vesting such control in the data owner such that data owners and data consumers (e.g., a service provider, a data requester, etc.) may interact with each other, allowing the data owner to control granting, denying, and revoking access (among other actions) to data of a data owner. Although described and depicted in the drawings as a "data consumer," a skilled artisan would understand that the systems and methods described herein apply to any entity that generates data on behalf of or associated with the data owner (such as a healthcare provider who generates a patient health record for the data owner) and/or any entity that seeks access to data of the data owner (such as an mortgage underwriter who seeks to review financial information of the data owner to complete the underwriting process).

Consent management and data visibility may be decoupled to allow data consumers to send a request to the data owner to access their data, without the data intermediary acting as a liaison between data owners and data consumers for data visibility. Additionally, data owners are able to grant, deny, and/or revoke access to their data without the data intermediary acting as a liaison. Data intermediaries may store user data, encrypted by the data owners as described below, while also governing access to the data repositories and implementing their own security protocols. To generate the encrypted records stored by the data intermediaries, data owners and data consumers may interact to grant, deny (e.g., reject), and revoke access through services provided by the data intermediary. While data intermediaries provide communication services between data owners and data consumers, they do not have visibility over data owner's records, as they are unable to decrypt them. The disclosed systems and methods may also allow a data owner to grant, deny (e.g., reject), and revoke access for one or more data consumers on a large scale, e.g., record-level access, one or more groups of related records, all of the data owner's data managed by a certain data intermediary. This gives the control of data visibility directly to the data owner.

According to the embodiments disclosed herein, aspects of the present disclosure include one or more systems and methods for record-level encryption of data. In some embodiments, the systems and methods described herein provide a party, such as a healthcare provider, the ability to generate a new record (e.g., file(s), document(s), and/or other types of digital content not limited to text such as video, audio, and images) and encrypt the record to preserve consent management with a data owner, such as a patient. Some embodiments describe systems and methods for a party (e.g., a data consumer) who may be the same party who generated the record (such as the healthcare provider in the example above) or a different party (such as an insurance company) to request access to the previously generated record that was stored by a data intermediary in an encrypted format. A data owner may be the subject of the data in the record (such as the patient in the example above). In some embodiments, the data owner may not generate the record, but be the owner of the record and data within the record. For example, a doctor may generate a patient file. While the data owner (e.g., the patient) may not have generated the file or data within the file, the patient may be the owner of the data (e.g., the patient's personal health data). For files, such as patient files, that contain sensitive information (e.g., health data, personal identifiable information (PII), and/or other data regarded as sensitive or requiring consent to view) the data owner may not manage the storage of those files; a third party (e.g., data intermediary) may be responsible for data storage. However, before a party is able to generate, access, view, edit, delete, etc., the records/files associated with the data owner, the data owner may have to give consent. Further, the data owner may decide to provide limited consent to a party, for example to only do one or more of generating, accessing, viewing, editing, or deleting records, and may limit the access of parties to only certain records or to certain records for certain periods.

The record-level encryption scheme allows a data owner to have consent management over their data, even though a third party may be managing the storage and security of the data. For example, when a patient wants to grant access to a health care professional to generate a new record for their file or patient profile, the patient may be able to grant access to the health care professional for the specific file. The patient may also give access to read, view, edit, and delete individual records within the patient file or profile. This provides an advantage over current systems that do not give data owner's the ability to grant, deny (e.g., reject), and revoke access to their data on an individual record-level. Conventional systems use a centralized approach where a data intermediary and/or a third-party broker provides storage, security, and data access services. However, the systems and methods disclosed herein provide a decentralized approach, which may allow the data owner and a data consumer to interface via a data visibility control platform application programming interface (API), such as by exchanging messages via a communications network. For example, the data owner may grant, deny (e.g., reject), and/or revoke consent for individual data consumers to read, write, edit, delete, etc., the data owner's data via the data visibility control platform API. The data owner may grant, deny (e.g., reject), and/or revoke access to specific data (e.g., files or records) of specific data consumers.

As described above, a data owner may be the subject and/or the legal owner of the data, even if they are not the generator and/or custodian of the data. A data consumer (e.g., user or requester) may be a person or entity that generated the data or a person or entity seeking access to the data owner's record(s), file(s), account, and/or the like. For example, a data owner may be a patient and a data consumer may be a doctor, a caregiver, or other healthcare provider. The data consumer could also be an insurance company, a different health care provider who cares for the patient (such as a specialist who seeks to review a primary care physician's notes), or a family member who is preparing a family medical history, to name a few examples. As would be apparent to a skilled artisan, the disclosure is not limited to the medical or insurance industries, and is applicable in any other context in which one party owns data and another party seeks to use or request access to the data. For example, the data owner may be an employee and the data consumer a human resources professional; the data owners may be citizens and the data consumer a governing body; the data owner may be a consumer (e.g., purchaser) and the data consumer a retail or utility organization; and the data owner may be an account holder and the data consumer a financial institution. There are many possible embodiments where a data owner and data consumer may use the record-level encryption scheme to provide decentralized consent management for the records of the data owner and the examples provided herein are not intended to be limiting. The framework for decentralized consent management of records described herein is applicable where a centralized entity generates data records on behalf of a data owner, which are then stored in centralized data storage. The framework is also applicable to artificial intelligence (AI) applications that use data to train AI models. The framework would allow data owners to choose which of their data records could be used to train an AI model.

Various embodiments of the disclosed technology will now be discussed with respect to the corresponding figures.

FIG. **1**A depicts a block diagram of a record-level encryption environment **100**, according to some embodiments. Record-level encryption environment **100** may include one or more data owner device **110**, one or more data consumer device **120**, network **130**, data visibility control platform **140**, and one or more data intermediary(ies) **150**. In some embodiments, data owner device **110** and data consumer device **120** may communicate over network **130**. Network **130** may facilitate communications between data visibility control platform **140** and devices accessing network **130**, such as data owner device **110** and data consumer device **120**. Data owner device **110** and data consumer device **120** may access data visibility control platform **140** over network **130** via an API (e.g., web-server application, web-client application, and/or native application). Data owner device **110** and data consumer device **120** may utilize data visibility control platform **140** to generate, delete, edit, view, and/or read records containing data of the data owner.

Data owner device **110** and/or data consumer device **120** may use hardware or software capable of generating and securely storing cryptographic keys to encrypt and decrypt payloads, e.g., records, cryptographic keys, and/or other data transmitted between devices in record-level encryption scheme **100**. In some embodiments, data owner device **110** and data consumer device **120** may be a smart phone, smart watch, desktop, laptop, notebook computer, netbook, tablet, personal digital assistant (PDA), and/or other communication devices which may be used to communicate over network **130**, to name a few non-limiting examples. In some embodiments, an application (which may or may not be browser-based) may provide a user interface for data visibility control platform **140** on data owner device **110** and/or data consumer device **120**. Selectable objects, buttons, or other interface elements may be provided for a user to register for data visibility control platform **140**, grant/deny/revoke access for data consumers, encrypt/decrypt records, and generate, delete, edit, view, and/or read one or more records, to name a few non-limiting examples.

The record-level encryption scheme disclosed herein may employ symmetric, asymmetric, and/or hybrid cryptography. In some embodiments, data owner device **110** may generate cryptographic keys, such as those described in FIGS. **2**A, **2**B, and **2**C. The cryptographic keys may include one or more public-private key pairs of the data owner, one or more public-private key pairs of the data consumer, as well as record keys that are used to encrypt records stored in record database **160**. In some embodiments, a hybrid encryption model using both symmetric and asymmetric encryption schemes may be utilized.

Record-level encryption environment **100** may include network **130**. Network **130** may be a wireless network and/or a combination of wired and wireless networks. For example, network **130** may include a packet-switched network (e.g., internet protocol-based network), a non-packet switched network (e.g., quadrature amplitude modulation-based network), and/or the like. According to some aspects of this disclosure, network **130** may include network adapters, switches, routers, modems, and the like connected through wireless links (e.g., radiofrequency, satellite) and/or physical links (e.g., fiber optic cable, coaxial cable, Ethernet cable, or a combination thereof). According to some aspects of this disclosure, network **130** may include public networks, private networks, wide area networks (e.g., Internet), local area networks, and/or the like. According to some aspects of this disclosure, network **130** may provide and/or support communication from a telephone, cellular phone, modem, and/or other electronic devices. For example, network **130** may include and support communications among data owner device **110**, data consumer device **120**, data visibility control platform **140**, and/or data intermediary **150** via network **130**.

Record-level encryption environment **100** may include data visibility control platform **140**, which may manage secure access to stored data. Data visibility control platform **140** may provide a platform for data owners and requesters to register for a record-level encryption scheme. In some embodiments, data visibility control platform **140** may also track whether access to records have been granted, denied, or revoked from a data owner to a requester. Data visibility control platform **140** may also provide an infrastructure and method for data owners to interface with data consumers. In some embodiments, data owners and data consumers may first register within data visibility control platform **140**. When a data owner registers with data visibility control platform **140**, the data owner may provide sufficient information to authenticate themselves and allow data visibility control platform **140** and data intermediary **150** to identify existing data of the data owner, e.g., records, files, and/or other forms of electronically stored data associated with the data owner. For example, the data owner may be required to submit an identifier capable of verifying their identity such as a social security number, Public Digital Identity System (SPID) credentials, or other credentials. In some embodiments, data visibility control platform **140** may require multiple identifiers such as both a: (1) social security number; and (2) copy of a birth certificate.

In some embodiments, data consumers may register with data visibility control platform **140** as entities and/or individuals. For example, in the health care system, a patient may register with data visibility control platform **140** and the full patient file may then be associated with the data owner, e.g., patient, such that the patient may begin to grant, deny, and revoke access to a data consumer. A data consumer, e.g., a health care professional, may register to request access to existing patient files, edit and review patient files, and/or generate additional patient files to be electronically stored and managed by data intermediary **150**. Similar to the data owner, data consumers may also be required to submit one or more identifiers to verify their identity.

Data visibility control platform **140** may be accessed by a web browser, a hybrid or a native web application, and/or application programming interface (API), etc., which is accessible by data owner device **110** and/or data consumer device **120**. Data visibility control platform **140** may utilize backend services to process and store data owner and data consumer registration. Data visibility control platform **140** may also process and store data consumers' granted, denied, or revoked access status for data owner records. In some embodiments, data visibility control platform **140** may be utilized for backend services to provide direct communication between data owners and data consumers. Under a conventional approach, data owners have little control over their data-rather, the party who creates the data (e.g., a medical provider generating a medical record of a patient's visit) typically controls access to the data, often via a third-party data intermediary (e.g., a medical records service). For example, a medical provider may generate a record of a patient's visit, and provide the patient with access to the record via a patient portal (which may be maintained by a third-party service provider). Typically, the patient does not control their own data; that is, they cannot grant, deny, or revoke access rights to their medical records. By contrast, the data visibility control platform **140** empowers data owners to control their data. Data owners and data consumers may communicate with each other, without interfacing indirectly through a data intermediary, to grant/deny/revoke access to records of a data owner. In some embodiments, data intermediary **150** may confirm a data consumer has access to record(s) of a data owner via data visibility control platform **140**. This provides a significant advantage over conventional systems, particularly when a data owner's records may be stored by multiple data intermediaries and a data owner may have to interface with each data intermediary to control visibility of their data (e.g., records). Data visibility control platform **140** provides an interface to control data visibility in real-time, regardless of the data intermediary storing the data owner's data.

In some embodiments, data visibility control platform **140**, as described in FIG. **1**B, may provide infrastructure or access to third party services including front-end **142**, back-end processor **144**, key generating service **146**, and/or entropy source **148** to be used by data owner device **110** and/or data consumer device **120**. The back-end processor **144**, key generating service **146**, and/or entropy source **148** may be used to generate the various public and private cryptographic keys for data owner device **110** and/or data consumer device **120** that are used in the asymmetric, symmetric, and/or hybrid encryption schemes disclosed herein. In some embodiments, data owner device **110** and/or data consumer device **120** may interact with front-end **142** and data visibility control platform **140** using back-end processor **144** and/or key generating service **146** for encryption and decryption of records. Additionally, back-end processor **144** may be used to add additional security measures, such a digital signatures and/or digital certificates.

In some embodiments, record-level encryption environment **100** may include data intermediary **150** and record database **160**. Data intermediary **150** may provide security and storage services for the data of the data owner. In some embodiments, the data may be in the form of records, files, and/or other forms of electronically stored data associated with the data owner. In some embodiments, data may be generated, read, and/or edited via data owner device **110** and/or data consumer device **120**. Record database **160** may be managed by data intermediary **150**. In some embodiments, data owners and consumers may not interact with data intermediary **150** and/or record database **160**. Data owners and consumers may interact with each other and with data visibility control platform **140**. Data visibility control platform **140** may communicate any grant or revocation of access to data by the data owner with data intermediary **150**, which may be responsible for access governance and security protocols of the stored data. In some embodiments, data visibility control platform **140** may store the access status for data owner records and data consumers and provide the status to data intermediary **150** upon request from data intermediary **150**. In some embodiments, data visibility control platform **140** may provide the status to data intermediary in real-time, in response to a change in status, and/or periodically. Additionally, for data and/or record access, data visibility control platform **140** may provide the platforms to electronically share the record. In some embodiments, data visibility control platform **140** and/or data intermediary **150** may utilize a data sharing platform to provide access to the data and/or records stored via record database **160**. The data intermediary platform may also be responsible for security and/or privacy control functions. For example, data sharing based on message queuing protocols, such as AMQP, etc., may be utilized by data visibility control platform **140** and/or data intermediary **150**. Regardless of the protocol used for data sharing, the data visibility control platform **140** may provide secure data and provide secure access to the data using hardware- and/or software-based security techniques.

As described above, record database **160** may store encrypted records generated by data owners and/or data consumers. Data and/or records stored in record database **160** may be accessed by the data owner and/or data consumers that have been granted records access through data visibility control platform **140**. Record database **160** may store data and/or records on-site, remotely, or a combination of both. In some embodiments, data intermediary **150** may employ a plurality of records databases **160**. Additionally, in some embodiments, record database **160** may be a third-party database, data broker, one or more blockchains, and/or data storage service.

FIG. **1**B depicts a detailed block diagram of an example data visibility control platform **140** and interactions with data owner device **110** and data consumer device **120** in record-level encryption environment, according to some embodiments. Communications may occur through a communication network, such as network **130** of FIG. **1**A. Data visibility control platform **140** may include or provide data owner device **110** and/or data consumer device **120** access to front-end **142**, back-end processor **144**, key generating service **146**, and/or entropy source **148**. Data visibility control platform **140** may use front-end **142**, back-end processor **144**, key generating service **146**, and/or entropy source **148** to register data owner device **110** and/or data consumer device **120**, generate cryptographic keys (such as the public and private keys described herein), and/or allow data owners to grant/deny/revoke access to the data owner's data (e.g., data owner's records containing sensitive information).

This intermediate stack of components **142-148**, including front-end **142**, back-end processor **144**, key generating service **146**, and entropy source **148** may optionally be centralized, distributed, or otherwise decentralized. Any key generating service **146** and entropy source **148** are optional with respect to data visibility control platform **140**. For example, data owner device **110** and data consumer device **120** may be configured to generate their own cryptographic keys (e.g., public-private key pairs, record keys, private (shared) keys).

In some embodiments, front-end **142** may provide a user interface for the data owner and/or data consumer. The user interface may be accessed via a web browser, hybrid or native web application, and/or application programming interface (API), etc., accessible on data owner device **110** and data consumer device **120**. This interface may allow the data owner to maintain visibility over data consumers. For example, front-end **142** may display the data consumers who have been granted access to records or data of the data owner or had access revoked. Front-end **142** may further display requests by data consumers that have been denied. The data owner may be able to grant, deny, or revoke access by interacting with the user interface displayed by front-end **142** on data owner device **110**. Front-end **142** may also be used by the data owner to grant, deny, and revoke data access to any given data consumer, at any time, for any reason. For example, front-end **142** may display a request from a data requester such as data consumer device **120**. The request may include various information such as an identity of the data requester, a time, a reason, and/or a location from which the request originated. The data owner may use front-end **142** to grant or deny the request. In some embodiments, these operations may be executed by back-end processor **144**.

As described in FIGS. **2A-2C**, a data consumer may seek to generate a record containing sensitive or confidential data of a data owner, additionally a method for reading records is described in FIGS. **4A-4C**. These described methods use cryptographic keys to securely transmit the sensitive data of the data owner. The components of FIG. **1**B may be used by data owner device **110** and/or data consumer device **120** to generate cryptographic keys. Data visibility control platform **140** may provide access to and/or use front-end **142**, back-end processor **144**, key generating service **146**, and/or entropy source **148** to generate cryptographic keys to encrypt and decrypt the data (e.g., records) and/or other cryptographic keys. For example, back-end processor **144** or key generating service **146** may have at least one entropy source by which to provide random seed data for cryptographic key generation, either at the back-end processor **144**, data owner device **110**, and/or at data consumer device **120**, according to some embodiments.

In some embodiments, data owner device **110** and/or data consumer device **120** may generate cryptographic keys to transmit data and/or cryptographic keys within record-level encryption environment **100** as described with reference to FIGS. **2A-2C** and **4A-4C**. For example, data owner device **110** may generate the public and private keys that are used to encrypt and decrypt records and/or other cryptographic keys. Data owner device **110** may also generate one or more record keys. Data owner device **110** and data consumer device **120** may include hardware and/or software capable of generating and securely storing cryptographic keys. In some embodiments, data owner device **110** and/or data consumer device **120** may generate public and private keys (including public-private key pairs) when the data owner and/or the data consumer register for data control visibility platform **140**. In addition or as an alternative to storing keys locally on the data owner device **110** or data consumer device **120**, certain keys may be sent to a key vault and stored for later use to execute the methods described in FIGS. **2A-2C** and

4A-**4**C. As described in more detail below, asymmetric cryptography, symmetric cryptography, and/or a combination of both (hybrid encryption) may be used to exchange information within the system disclosed herein.

In some embodiments, multiple sets of public-private key pairs may be utilized. For example, a first public-private key pair may be used for communication between data owner device **110** and data consumer device **120** (e.g., a communication key pair). A second public-private key pair may be generated for encrypting and decrypting record keys (e.g., a key encryption pair). Utilizing two sets of key pairs may be beneficial to increase network and computer security within record-level encryption environment **100**. Each key pair may be updated or changed at different frequencies based on various needs. As will be discussed below with reference to FIGS. **3**A, a key identifier or key index may be stored in association with the public-private key pairs to determine which public-private key pair was used to encrypt a record, a record key, and/or a communication.

For example, a first record may be encrypted using public-private key pair A. Next, a new public-private key pair B may be generated and used to encrypt subsequent records. When a request to decrypt the first record is received, a lookup may be performed to identify that key pair A was used to encrypt the first record. As a result, key pair A, instead of key-pair B, may be used to decrypt the first record.

Additionally, keys used to encrypt and decrypt records may be updated or rotated. As will be discussed in more detail below, record keys may be used to encrypt records stored in record database **160**. The record key may be encrypted using a data owner's private key, and then stored. In some embodiments, the encrypted record key may be stored in a storage device. In some embodiments, the storage device includes a blockchain platform. The data owner may update the record key. The record key may be updated at any frequency such as once an hour, once a day, once a week, once a month, once a quarter, to name a few non-limiting examples. Events other than the passage of time may also trigger updating one or more record keys, such as suspicious activity associated with the data owner, which may include suspicious activity targeting the data owner or suspicious activity from a data owner themselves, such as activity that is inconsistent with the data owner's past behaviour (such as suddenly granting record access to a large number of data consumers) or granting access to a known fraudulent entity. When the record key is updated, the data owner may choose to re-encrypt the records that were encrypted using the previous record key. Here, the data owner may perform a re-encryption process using the new record key.

To perform this operation, the data owner may retrieve the encrypted record from storage (e.g., record database **160**) and retrieve the encrypted record key from the blockchain platform. The data owner may then decrypt the encrypted record key using a private key. The data owner may then decrypt the encrypted record with the record key. Subsequently, the data owner may generate a new record key, and use it to encrypt the record. Once encrypted, the record may be stored at record database **160**. The new record key may also be encrypted using a private key, and stored on a blockchain platform. In some embodiments, the data owner may delete the old record key. As discussed above, a key identifier may be stored in association with the encrypted record key. The key identifier may correspond to the private key used to encrypt and decrypt the encrypted record key. In some embodiments, a transaction identifier may be generated and used to map an association between: (1) an encrypted version of a record; (2) a cryptographic hash of an unencrypted version of the record; (3) a key used to encrypt the record (e.g., an encrypted record key); and (4) a key identifier corresponding to a key used to encrypt the record key. The data owner may generate and use a new record key every time the data owner encrypts a record.

In some embodiments, certain private keys may be shared with trusted parties. For example, data owner device **110** may be configured to share certain private keys with law enforcement in the event of a criminal investigation. Similarly, data owner device **110** may be configured to share certain private keys with medical personnel, a designated family member, a medical proxy, etc., during a medical emergency.

FIG. **2**A depicts an example process for providing record-level encryption for a newly generated record that employs asymmetric cryptography. For the purposes of the example provided in FIG. **2**A, the data owner and the data consumer have previously registered with data visibility control platform **140**.

In the embodiment of FIG. **2**A, data owner device **110** employs asymmetric cryptography (or public-key cryptography) to generate and/or store at least one public-private key pair (e.g., data owner public key **210** and corresponding data owner private key **230**). The public-private key pair may have a corresponding identifier. The identifier may be any value used to uniquely identify the key pair (e.g., a letter, number, word, and phrase). In some embodiments, the public key may be used as the identifier. In some embodiments, data owner device **110** may also generate and/or store one or more individual encryption keys, such as private, record keys that are discussed in more detail below. Identifiers may also be generated for individual encryption keys. In some embodiments, a third-party certificate authority may generate a public-private key pair for data owner device **110**. Keys may be stored locally at data owner device **110**, at third-party storage, or a combination thereof. For example, private keys may be stored in computer memory that is secured using hardware and/or software techniques to prohibit unauthorized access to the private keys. In some embodiments, data owner device **110** may store generated encryption keys in a third-party key vault, such as a remote secure vault. In some embodiments, data owner device **110** may store encryption keys in a cold storage system without internet access. In some embodiments, key identifiers may be stored at the same location as the keys they identify.

In some embodiments, data owner device **110** transmits one or more data owner's public keys, such as data owner public key **210**, to data consumer device **120** via network **130** communication. Data owner device **110** may also publish or post (e.g., to a website) or broadcast the one or more data owner public keys, such as data owner public key **210**, such that data consumers can access the one or more data owner public keys. Data owner device **110** may publicize the one or more data owner public keys, wherein publicizing includes transmitting, broadcasting, publishing, posting, and/or any other mechanism for publicly disclosing data owner public keys. To further enhance security, keys generated by the data owner or the data consumer may expire after a certain period (e.g., 1 hour, 1 day, 1 week, 1 month, etc.) or based on a triggering event (e.g., a record was accessed 5 times, a record was edited, a record was sought to be accessed with a high frequency (which may indicate fraudulent attempts, etc.), and new keys may be generated and used. New keys may be generated and used a regular time intervals, on demand, or based on triggering events.

The data owner may utilize an interface of data visibility control platform **140** to transmit one or more data owner public keys, such as data owner public key **210**, to a specified data consumer device **120**. In some embodiments, prior to sending data owner public key **210**, data owner may receive a notification that the specified data consumer requests the ability to generate one or more documents that will be associated with the data owner and stored via data intermediary **150** and/or record database **160**. In some embodiments, when a data owner grants access to an entity to generate and/or delete records associated with or on behalf of the data owner (such as a healthcare provider), the entity may be granted the ability to repeat the process described herein to generate new records containing data of the data owner as needed until access has been revoked. For example, a patient (data owner) may grant their primary care physician the ability to generate multiple records, each of which is encrypted and stored using the systems and methods described herein.

Data consumer device **120** may receive data owner public key **210** from data owner device **110**. Data consumer device **120** may generate a record, e.g., file, document, and/or electronically stored data, including data of the data owner. In some embodiments, the data may be sensitive and or confidential data of the data owner, such as medical information, health data, financial data, PII, and/or similarly sensitive and/or confidential data. Data consumer device **120** may use data owner public key **210** to encrypt the newly generated record. Data consumer device **120** may include hardware and/or software capable of generating cryptographic keys and encrypting records. Data consumer device **120** may access one or more web applications and/or native applications, e.g., for general-purpose computers (PC, kiosk, etc.), mobile devices (e.g., tablet, smartphone, etc.), to encrypt the record (e.g., encrypted record **220**A). Data consumer device **120** may provide a user interface for data visibility control platform **140**.

In some embodiments, encrypted record **220**A, encrypted with data owner public key **210**, may be uploaded from data consumer device **120** to data intermediary **150** via network **130**. Data consumer device **120** may interact with the user interface of data visibility control platform **140** via front-end **142**, to upload encrypted record **220**A to data intermediary **150**.

Data intermediary **150** may receive encrypted record **220**A. Data intermediary **150** may transmit a notification to data owner device **110** comprising a message indicating encrypted record **220**A has been uploaded from data consumer device **120**. Data intermediary **150** may transmit the notification to data owner device **110** via network **130**. In some embodiments, data intermediary **150** may transmit the notification via data visibility control platform **140**. Data visibility control platform **140** may use front-end **142** to display the notification on the user interface. Data owner device **110** may receive the notification that a new record associated with the data owner and/or the data owner device **110** has been uploaded to the data intermediary **150**. Similarly, in some embodiments, data consumer device **120** may transmit the notification to the data owner device **110**, which may be displayed via the user interface of front-end **142**.

The notification may indicate that encrypted record **220**A has been uploaded from data consumer device **120**. The data owner may interact with the user interface of front-end **142** to download encrypted record **220**A from data intermediary **150**. In some embodiments, encrypted record **220**A may be downloaded from data intermediary **150** to data owner device **110** via network **130**. Data owner device **110** may use data owner private key **230** to decrypt the encrypted record **220**A, generating decrypted record **220**B, which may be stored locally by data owner device **110**. Data owner device **110** may use back-end processor **144** and/or key generating service **146** provided by data visibility control platform **140** to decrypt encrypted record **220**A using data owner private key **230** to generate decrypted record **220**B. Decrypted record **220**B may be unencrypted, cleartext of the document that was generated by data consumer device **120**. In some embodiments, decrypted record **220**B may be referred to as a "clear record" or "cleartext" or "plaintext." As discussed above, the technology disclosed herein applies to any type of digital content including (but not limited to) text, video, audio, and images.

FIG. **2**B depicts an example process for providing record-level encryption for a newly generated record the employs a hybrid encryption model that uses both symmetric and asymmetric cryptography. The data owner device **110** may generate a private (shared) key **215**A, a copy of which is shared with data consumer device **120** with the understanding that the data owner and the data consumer do not share the private key **215**A with other entities; that is, the private (shared) key **215**A is a shared secret. Private (shared) key **215**A may be a symmetric key used to encrypt and decrypt data. As described herein, the data owner device **110** may include the hardware and/or software necessary for generating the private (shared) key **215**A or the data owner device **110** may invoke another entity, such as a third-party certificate authority to generate the private (shared) key **215**A. The private (shared) key **215**A, may be stored in computer memory that is secured using hardware and/or software techniques to prohibit unauthorized access to the private keys. In some embodiments, data owner device **110** may store generated encryption keys in a third-party key vault, such as a remote secure vault. In some embodiments, data owner device **110** may store encryption keys in a cold storage system without internet access.

In order to initially share private (shared) key **215**A, data owner device **110** may utilize asymmetric encryption. For example, data owner device **110** may utilize data consumer public key **212** to encrypt private (shared) key **215**A. The result may be encrypted private (shared) key **215**B. Data owner device **110** may retrieve data consumer public key **212** via communication over network **130**. Data consumer device **120** may also publish or post (e.g., to a website) or broadcast data consumer public key **212** such that data owners can access data consumer public key **212**. Data consumer device **120** may publicize data consumer public key **212**, wherein publicizing includes transmitting, broadcasting, publishing, posting, and/or any other mechanism for publicly disclosing data consumer public key **212**. Data consumer device **120** may securely store the private (shared) key **215**A using any of the same techniques described above with respect to the data consumer device **110**.

Data consumer device **120** may receive encrypted private (shared) key **215**B, and utilize data consumer private key **213** to decrypt encrypted private (shared) key **215**B. Once decrypted, data consumer device **120** may be able to utilize private (shared) key **215**A to securely exchange information with data owner device **110**. For example, as discussed above, data consumer device **120** may generate a record. Data consumer device **120** may encrypt the record with private (shared) key **215**A, resulting in encrypted record **220**A. As stated above, data consumer device **120** may interact with the user interface of data visibility control platform **140** via front-end **142**, to upload encrypted record **220**A to data intermediary **150**.

Data intermediary **150** may transmit a notification to data owner device **110** comprising a message indicating encrypted record **220**A has been uploaded from data consumer device **120**. The data owner may interact with the user interface of front-end **142** to download encrypted record **220**A from data intermediary **150**. In some embodiments, encrypted record **220**A may be downloaded from data intermediary **150** to data owner device **110** via network **130**. Data owner device **110** may use private (shared) key **215**A to decrypt encrypted record **220**A. As a result, data owner device **110** may view the unencrypted contents of the record (e.g., decrypted record **220**B).

Using the hybrid encryption model described above, data owner may generate a private (shared) key for each data consumer with which the data owner interacts. For example, the data owner may generate private (shared) key K1 that is shared with and used to securely exchange information with their healthcare provider. The same data owner may generate private (shared) key K2 that is shared with and used to securely exchange information with their automobile insurance company. The same data owner may generate yet another private (shared) key K3 that is shared with and used to securely exchange information with their bank.

FIG. **2**C depicts an example process for storing an encrypted record in a records database using a record-level encryption scheme. Data owner device **110** may generate and/or store one or more private, record keys, such as record key **240**A. As discussed above, data owner device **110** may store generated keys, such as record key **240**A locally or at a third-party key vault, such as within a cold storage device or remote secure vault. In some embodiments, data owner device **110** may use back-end processor **144**, key generating service **146**, and/or entropy source **148** provided by data visibility control platform **140** to generate record key **240**A. Record key **240**A may be specific to the record generated by data consumer device **120**. Data owner device **110** may generate a record key **240**A for each record added to data intermediary **150** and/or stored by record database **160** that is associated with the respective data owner.

Data owner device **110** may encrypt record key **240**A using data owner public key **210** to generate encrypted record key **240**B. Data owner device **110** may use data visibility control platform **140** to store encrypted record key **240**B on blockchain platform **250**. In some embodiments, data owner device **110** may further use data visibility platform **140** to store an identifier (e.g., key identifier **224**) corresponding to public key **210** used to generate encrypted record key **240**B. This may be beneficial in a scenario where data owner device **110** generates and uses multiple public-private key pairs, and needs to keep track of which key pair was used to encrypt record key **240**A. Key generating service **146** may forward or store encrypted record key **240**B to blockchain platform **250**. In some embodiments, key generating service **146** may further forward or store key identifier **224** to blockchain platform **250** . . . . Key generating service **146** and/or blockchain platform **250** may use a smart-contract interface, to store encrypted record key **240**B. Data visibility control platform **140** may utilize any suitable blockchain platform, such as Ethereum or another platform, e.g., supporting smart contracts, and decentralized applications, for example, but any other blockchain platform supporting similar features may be used (e.g., Hyperledger), or a non-blockchain solution (e.g., database) may be used, in some embodiments.

Data owner device **110** may be further configured to generate cryptographic hash **222** of the unencrypted record. Data owner device **110** may directly generate cryptographic hash **222**. In some embodiments, data owner device **110** may use back-end processor **144**, key generating service **146**, and/or entropy source **148** provided by data visibility control platform **140** to generate cryptographic hash **222**. Cryptographic hash **222** may be generated using any hashing algorithm, such as MD5, SHA-1, etc. Cryptographic hash **222** may be unique to the contents of the encrypted record. Data owner device **110** may transmit cryptographic hash **222** for storage at blockchain platform **250**. Data owner device **110** may use data visibility control platform **140** to store cryptographic hash **222** on blockchain platform **250**. Key generating service **146** may forward or store cryptographic hash **222** to blockchain platform **250**.

Blockchain platform **250** may generate transaction identification (ID) **260** when data visibility control platform **140** propagates encrypted record key **240**B from data owner device **110**. Encrypted record key **240**B may be stored on the blockchain of blockchain platform **250**. In some embodiments, the blockchain may store transaction ID **260**, encrypted record key **240**B, and a cryptographic hash **222** of the record. Blockchain **250** may further store key identifier **224**, identifying the key or key-pair used by data owner device **110** to encrypt encrypted record key **240**B. FIG. **3**A depicts an example of a record stored on the blockchain. Cryptographic hash **222** may be used to verify if record key **240**A can decrypt encrypted record **220**C. Additionally, cryptographic hash **222** can be used by data owner device **110** and/or data consumer device **120** to verify encrypted record **220**C has not been tampered with. For example, data owner device **110** may retrieve (from a data intermediary) encrypted record **220**C, decrypt it, and calculate the hash of the decrypted record. Data owner device **110** may then compare this hash to cryptographic hash **222** stored on blockchain **250**. If the values differ, this may be an indication that the contents of the record retrieved from the data intermediary has changed or been tampered with. In some embodiments, blockchain platform **250** may store a plurality of encrypted record keys **240**B and corresponding transaction IDs **260**, one for each record generated by data consumer device **120**. Each record may have a unique record key and transaction ID associated with storing the encrypted record key on blockchain platform **250**. In some embodiments, blockchain platform **250** transmits transaction ID **260** to data owner device **110** when encrypted record key **240**B has been propagated to the blockchain. Using blockchain platform **250** to store encrypted record keys in the systems and methods disclosed herein has certain technical advantages over conventional systems. For example, using blockchain platform **250** to store and maintain record keys is more efficient for the user's device because less memory needs to be allocated to store and organize the record keys. The blockchain platform **250** also provides redundant storage of the user's record keys. In a system in which a user's keys are only stored locally, if the user's device is damaged or malfunctions, for example, and their stored keys could not be retrieved, all of their data would be lost. By contrast, the disclosed systems and methods use of blockchain platform **250** ensures secure, redundant, external storage of a user's record keys. Thus, if the user's device is damaged or malfunctions, they can still retrieve their record keys, such as by using another device.

Data owner device **110** encrypts the decrypted record **220**B using record key **240**A to generate encrypted record **220**C. Data owner device **110** may perform this operation locally, using back-end processor **144** and/or key generating service **146** of data visibility control platform **140**, or some combination of local and remote processing. Record key

240A may be used to re-encrypt decrypted record **220**B before or after record key **240**A is encrypted with data owner public key **210**.

Data visibility control platform **140** may transmit encrypted record **220**C, encrypted with record key **240**A, to data intermediary **150**. Data intermediary **150** may use record database **160** to store encrypted record **220**C. In some embodiments, the data intermediary includes one or more record databases. In other embodiments, the data intermediary has access to and control over one or more record databases, such as cloud databases provided by a third-party or databases provided by a service provider (such as a healthcare service provider that may or may not be the same as the data consumer). This method enhances security to records stored in record database **160**, including by not relying on the data intermediary to provide both visibility control and access and/or security controls. For example, by encrypting each record with its own user-generated record encryption key, even if record database **160** is successfully hacked, a bad actor would need to obtain every key in order to obtain access to the plaintext of every record of a given user. Further, when encrypted record key **240**B is propagated to blockchain **250**, it is stored on blockchain platform **250** and identifiable via transaction ID **260**. As an added layer of security, record key **240**A is propagated to the blockchain as encrypted record key **240**B which can only be decrypted using data owner private key **230**. Therefore, simply knowing transaction ID **260** to obtain encrypted record key **240**B from blockchain platform **250** is still not enough to use record key **240**A to decrypt encrypted record **220**C. By contrast, in a known system in which all of the data records of a user are stored together, a successful hack can expose all of the user's records.

FIG. **3**A depicts an example record stored on a blockchain, according to some embodiments. As depicted in FIG. **3**A, blockchain platform **250** may be configured to store one or more transaction IDs **260**. Each transaction ID **260** may correspond to cryptographic hash **222**, encrypted record key **240**B, and key identifier **224**. For example, a first transaction ID **260.1**, may correspond to: cryptographic hash **222.1**, encrypted record key **240**B.**1**, and key identifier **224.1**. As discussed above, blockchain platform **250** may generate transaction ID **260** in response to receiving encrypted record key **240**B. Cryptographic hash **222** may be used to determine whether the contents of decrypted record **220**B have been modified. Key identifier **224** may be used to determine which key or key pair was used to encrypt encrypted record key **240**B.

In some embodiments, there may be as many transaction IDs and encrypted record keys as there are encrypted records and cryptographic hashes associated with the data owner, e.g., transaction IDs **260.1-260.5** and record keys **240**A.**1-240**A.**5** corresponding to encrypted records **220**C.**1-220**C.**5** and cryptographic hashes **222.1-222.5**. While FIG. **3**A shows five transaction ID/cryptographic hash/encrypted record key/key identifier entries, a skilled artisan would have understood that storing tens, hundreds, thousands, millions, etc., of records associated with a data owner, which may be organized in any file structure, is within the scope of this disclosure. Some embodiments may store only transaction IDs and encrypted record keys, other embodiments store transaction IDs, cryptographic hashes, encrypted record keys, and key identifiers (as shown in FIG. **3**A), or any combination thereof.

FIG. **3**B depicts example storage of a plurality of transaction IDs encrypted records associated with a data owner. As depicted in FIG. **3**B, data intermediary **150** maintains transaction IDs **260** and the corresponding encrypted record **220**C, encrypted with record key **240**A. Data intermediary **150** may further maintain cryptographic hashes **222** corresponding to encrypted record **220**C. As stated above, cryptographic hash **222** may be computed based on decrypted record **220**B. Each transaction ID, such as transaction ID **260**, is associated with a corresponding encrypted record, such as encrypted record **220**C, and its accompanying cryptographic hash **222**. For example, transaction ID **260.1** is associated with a specific encrypted record **220**C.**1** encrypted with record key **240**A.**1**. Transaction ID **260.1** may be further associated with cryptographic hash **222.1**, based on the decrypted version of encrypted record **220**C.**1**. In some embodiments, there may be as many transaction IDs and record keys as there are encrypted records and cryptographic hashes associated with the data owner, e.g., transaction IDs **260.1-260.5** and record keys **240**A.**1-240**A.**5** corresponding to encrypted records **220**C.**1-220**C.**5** and cryptographic hashes **222.1-222.5**. While FIG. **3**B shows five transaction ID/encrypted record/cryptographic hash entries, a skilled artisan would have understood that storing tens, hundreds, thousands, millions, etc., of records associated with a data owner, which may be organized in any file structure, is within the scope of this disclosure. Some embodiments store only transaction IDs and encrypted records, other embodiments store transaction IDs, encrypted records, and cryptographic hashes (as shown in FIG. **3**B).

The transaction ID and corresponding information for records encrypted by specific record keys **240**A.**1** are stored using data intermediary **150**. Data intermediary **150** may store transaction IDs **260** and corresponding encrypted record **220**C and (optionally) cryptographic hashes **222** locally or remotely. As discussed with reference to FIG. **1**A, data intermediary may include or be associated with a database, such as record database **160**. In some embodiments, data intermediary **150** may store transaction IDs **260**, corresponding encrypted records **220**C, and hashes **222** in record database **160**.

In some embodiments, data intermediary **150** may store transaction IDs **260** (e.g., transaction IDs **260.1-260.5**), encrypted records **220**C (e.g., **220**C.**1-220**C.**5**), and cryptographic hashes **222** (e.g., cryptographic hash **222.1-222.5**). Data intermediary **150** stores the transaction ID(s) and associated encrypted record(s) and cryptographic hash(es), while the record key **240**A (that is used to encrypt the record) is encrypted and stored on the blockchain platform **250** (e.g., as encrypted record key **240**B of FIG. **2**C). In some embodiments, one or more data intermediaries **150** may store the data owner's records. For example, a first data intermediary **150** may store transaction IDs **260.1-260.2** and corresponding encrypted records **220**C.**1-220**C.**2** and cryptographic hashes **222.1-222.2** and a second data intermediary **150** may store transaction IDs **260.3-260.5** and corresponding encrypted records **220**C.**3-220**C.**5** and cryptographic hashes **222.3-222.5**.

Data intermediary **150** further enhances memory efficiency at the data owner's device because the data owner does not need to locally store the transaction IDs associated with their stored records. This is an added layer of security as record keys **240**A are identified using the corresponding transaction ID **260**. Data intermediary **150** stores both the transaction IDs **260** and encrypted records **220**C. However, even with the transaction IDs **260** and/or encrypted records **220**C, record keys **240**A are only stored on the blockchain of blockchain platform **250** as encrypted record keys **240**B. Encrypted record keys **240**B were encrypted with data owner public key **210** and may only be decrypted using data owner private key **230**. Therefore, if there was a security failure and a bad actor was able to access the transaction IDs **260** and/or encrypted records **220**C, they would still be unable to decrypt record keys **240**A without data owner private key **230**.

For example, transaction ID **260.1** and encrypted record **220**C.**1** is associated with record key **240**A.**1**. Record key **240**A.**1**, in turn, is encrypted using data owner public key **210**, and stored using blockchain platform **250**. Data intermediary **150** may store the transaction ID **260.1** associated with encrypted record **220**C.**1** and record key **240**A.**1** such that data owner device may use the transaction ID **260.1** to retrieve encrypted record key **240**B.**1** from blockchain platform **250**.

As will be discussed below, records at data intermediary **150** may be updated. As a result, a new cryptographic hash **222** may be calculated based on the updated record. In order to link the previous and modified record, the previous cryptographic hash **222** may be stored within the modified/updated version of the record. For example, when a new version of a record is created, a hash of the previous version of the record may be embedded in the new version of the record, which is then encrypted and stored according to the record-level encryption scheme disclosed herein.

FIG. **4**A depicts an example process for providing a data consumer access to a record stored with record-level encryption, according to some embodiments. The data consumer may be the same or a different entity than the entity that created the record. For example, a medical specialist may create a record of a patient's visit, which is subsequently encrypted and stored using the techniques of FIGS. **2**A-**2**C. Thereafter, the patient's primary care physician, insurance company, etc., may seek access to the patients record using the techniques of FIG. **4**A.

Data consumer device **120** may identify a record, such as encrypted record **220**C of FIG. **2**C that is stored in record database **160**. Data consumer device **120** may generate a request to access encrypted record **220**C, such as encrypted request **410**. The request may include the transaction ID (TID) of the desired record. In some embodiments, data consumer device **120** may not have access to the TID, and therefore not be able to include it within a request. Here, data consumer device **120** may include a description of information it is looking for within the request. For example, data consumer device **120** may be associated with a car insurance company, looking for medical records of a driver involved in a car accident. Here, the request may include details of the accident such as parties involved, date, time, and location. The request may further include purpose of use, requesting party identification, timestamp, and network through which the request was sent. In some embodiments, data visibility control platform **140**, data intermediary **150**, data owner device **110**, or a combination thereof, may determine TIDs of records corresponding to the request. In some embodiments, an artificial intelligence or machine learning based search engine may be used to identify TIDs matching the request. TIDs matching the request may be sent to data consumer device **120**. In some embodiments, only the TIDs may be sent to data consumer device **120** to ensure that the records are maximally protected. For example, descriptive record metadata, such as timestamp or record title, may not be provided to data consumer device **120**.

A request may also include purpose of use. The purpose of use may include how the record or data in the record will be used or processed by data consumer device **120** and why access is needed. For example the request may include level of access that the data consumer seeks (such as read only, edit, etc.) and/or the reason why access is needed, e.g., a healthcare provider may need to access records to perform a health assessment or upload new records to a patient's file. In some embodiments, permission to edit an existing record generates a new, modified version of the record that includes the edits while maintaining a copy of the un-modified record. In other embodiments, permission to edit an existing record modifies the existing record without maintaining a copy of the un-modified record. The request may also include information that enables the data owner to help evaluate whether the request should be granted, such as information that identifies the party making the request, a timestamp associated with the request, the communication network through which the request was transmitted, to name a few non-limiting examples. For example, a data owner who was recently in a car accident may expect one or more requests to access certain records from their automobile insurance company and from the automobile insurance company of the other party to the accident. But the same data owner may not expect an unrelated or unknown entity to request access to those records. Such a request from an unknown entity may indicate that the request is fraudulent and should not be granted. In some embodiments, the data consumer may encrypt the request using data owner public key **210** such that only the data owner can decrypt and review the request (using data owner private key **230**). In embodiments in which the data consumer and data owner maintain a shared private key (e.g., FIG. **2**B), the request may be encrypted using the shared private key (e.g., private (shared) key **215**A of FIG. **2**B). The data consumer may also digitally sign (using its own private key such as data consumer private key **440**) the request to enable the data owner to confirm that the request is from the data consumer by decrypting the request using the data consumer's public key, such as data consumer public key **420**. Data visibility control platform **140** may provide data consumer device **120** with access to the data owner public key **210** when data owner device **110** grants access to data consumer device **120** to data owner's records identified by the submitted TIDs.

In some embodiments, data consumer device **120** may transmit encrypted request **410** to data intermediary **150**. Data intermediary **150** may transmit encrypted request to data owner device **110**. In some embodiments, data consumer device **120** may use data visibility control platform **140** to transmit encrypted request **410** to data owner device **110** via the user interface of front-end **142**.

Data owner device **110** may decrypt encrypted request **410** using data owner private key **230** (or a private (shared) key, such as private (shared) key **215**A in embodiments in which the date owner and data consumer maintain a shared private key). Data owner device **110** may identify encrypted record **220**C and transaction ID **260** in the decrypted request. After decrypting the request, data owner device **110** may use transaction ID **260** identified in the decrypted request to retrieve encrypted record key **240**B from blockchain platform **250**. As described above with reference to FIG. **2**C, blockchain platform **250** generates transaction ID **260** when data owner device **110** propagates encrypted record key **240**B to blockchain platform **250**. Blockchain platform **250** stores transaction ID **260**, encrypted record key **240**B, and a corresponding document hash (e.g., cryptographic hash **222**) on the blockchain as a transaction. Blockchain platform **250** may further store key identifier **224** identifying the key or key-pair used by data owner device **110**.

FIG. **4**B depicts the continuation of the example process for providing data consumer access to a record stored with record-level encryption, according to some embodiments.

As described with reference to FIG. **4**A, data owner device **110** may decrypt encrypted record key **240**B with data owner private key **230** to retrieve record key **240**A associated with the requested record. Data owner **110** may use key identifier **224** to determine that data owner private key **230** may be used to decrypt encrypted record key **240**B. For example, data owner device **110** may maintain multiple public-private key pairs. Each key pair may have an identifier such as key identifier **224**. Data owner device **110** may use the key or key-pair corresponding to the identifier (e.g., key identifier **224**) returned by blockchain platform **250**. Data owner then encrypts record key **240**A using data consumer public key **420** to generate encrypted record key **430**.

Data owner device **110** may receive data consumer public key **420** in a variety of ways, including in a uni-cast or broadcast message received from data consumer, visiting a website on which the key is published, and from key generating service **146**, to name a few examples. As described in FIG. **1**B, data consumer device may use back-end processor **144**, key generating service **146**, and entropy source **148** to generate a public and private key pair (e.g., data consumer public key **420** and data consumer private key **440**.) In some embodiments, this data consumer device **120** may generate the cryptographic keys and key generating service **146** may store the public and private key pairs for later use, such as described in FIGS. **4**A-C. In some embodiments, a third-party certificate authority may generate a public-private key pair for data consumer device **120**. In some embodiments, data consumer device **120** may store generated encryption keys in a third-party key vault, such as a remote secure vault. In some embodiments, data consumer device **120** may store encryption keys in a cold storage system without internet access. Data owner device **110** may request access to data consumer public key **420** through data visibility control platform **140** via the user interface of front-end **142**.

After generating encrypted record key **430**, data owner device **110** may digitally sign encrypted record key **430** using data owner private key **230**. The digital signature may allow the data intermediary (who may have access to data owner public key **210**), and ultimately the data consumer, to demonstrate that the information was sent by the data owner. Data owner device **110** may then transmit encrypted record key **430** to data consumer device **120**. In some embodiments, data owner device **110** may use the user interface of front-end **142** to transmit encrypted record key **430** to data consumer device **120**. Data consumer device **120** may (when digitally signed) verify the digital signature using data owner public key **210** and decrypt encrypted record key **430** with data consumer private key **440**. In some embodiments, this decryption is done locally on data consumer device **120**. In other embodiments, data consumer device **120** may use back-end processor **144** and/or key generating service **146** provided by data visibility control platform **140** to decrypt encrypted record key **430**. When data consumer device **120** decrypts encrypted record key **430**, data consumer device **120** has access to record key **240**A. As described above and with reference to FIG. **2**C, encrypted record **220**C was encrypted with record key **240**A.

FIG. **4**C depicts the continuation of the example process for providing data consumer access to a record stored with record-level encryption, according to some embodiments. As described with reference to FIGS. **4**A and **4**B, data consumer device **120** requests encrypted record **220**C from data intermediary **150**. The encrypted record **220**C may be requested using the TID associated with encrypted record or any other information (e.g., title, date of record, general description of the record, to name a few examples) by which records are indexed in the data intermediary's database. In some embodiments, data intermediary **150** may confirm that the data owner has granted the requested permission to the data consumer (such as read, edit, etc.). The requested permission or level of access may be included in the request that the data consumer sends to the data owner. Data intermediary **150** may transmit encrypted record **220**C from record database **160** to data consumer device **120**.

Data consumer device **120** may decrypt encrypted record **220**C using record key **240**A. In some embodiments, such decryption is performed locally on data consumer device **120**. In other embodiments, data consumer device **120** may use back-end processor **144** and/or key generating service **146** provided by data visibility control platform **140** to decrypt encrypted record **220**C. By decrypting encrypted record **220**C with record key **240**A, requester device is able to access the plaintext of record **220**B.

In some embodiments, data consumer device **120** may read, or read and edit, decrypted record **220**B. In some embodiments, when editing a record, data consumer device **120** may read and edit the record and then send to data owner device **110** a request to store (to the records database via the data intermediary) a new, modified version of the record that contains the edits. Data consumer device **120** may use the process described in FIGS. **2**A, **2**B, and **2**C to start the process required to save the new, modified version of the record while maintaining a copy of the unmodified version of the record. Additionally or alternatively, the framework may allow the data consumer device **120** to send the data owner device **110** a request to overwrite an existing record with the new, modified version of the record without maintaining a copy of the un-modified version of the record.

As shown and described throughout, all communications between data owner device **110** and data consumer device **120** may employ layers of encryption to prevent unauthorized access to the information and to authenticate (e.g., using digital signatures) the parties that are exchanging the information. Data owner private key **230** and requester private key **440** are kept secret by the data owner and the data consumer, respectively.

FIG. **5** depicts an example framework **500** for data owner and requester registration for a record-level encryption scheme, according to some embodiments. To encrypt and share documents on the record-level as shown and described in FIGS. **2**A-**4**C, data owners and requesters may register with data visibility control platform **140**. During registration, data visibility control platform **140** may confirm the identities of the individuals and/or entities registering as data owners and/or data users/requesters. A skilled artisan would understand that data owners may be data users/requesters in some circumstances, and data users/requesters may be data owners in some circumstances. For example, in a medical provider-patient relationship, both parties may own sensitive or confidential data that the other party may seek access to. In some embodiments, participant registry **510** stores data owners and requesters who have registered with data visibility control platform **140**.

As shown in FIG. **5**, data owners and requesters may communicate with data intermediary **150** regarding access of records, as described with reference to FIGS. **2**A-**4**C. Data intermediary **150** may communicate with data visibility control platform **140** to ensure that data owners and requester are registered. For particular records, data intermediary **150** may confirm that data owner device **110** has granted access to consumer device **120** for a given record.

Document level access registry **520** may track access for records associated with each data owner. Data owner device **110** may grant, deny, reject, and/or revoke access to records managed by data intermediary **150** and stored (encrypted with the methods described above) in record database **160** via data visibility control platform **140**. If a data owner decides they no longer want to grant access to a given requester, they may revoke access via document level access registry **520** of data visibility control platform **140**. For example, a requester may be a medical provider with access to data owner's patient records managed by data intermediary **150** and stored in record database **160**. Data owner may transfer their medical care to a different medical provider. Data owner device **110** may access data visibility control platform **140** to revoke the access of the previous medical provider for all records within data owner's patient file. Data owner device **110** may be further configured to deny (e.g., reject) access requested by a requester. For example, a requester (e.g., data consumer device **120**) may send a request for a record belonging to a data owner associated with data owner device **110**. In response, data owner device **110** may deny the request. For example, data owner device **110** may interface with front-end **142** to deny the request. The data owner may deny the request for any reason such as: (1) a time of the request; (2) an identity of the requester; (3) a location the request originated from; or (4) a reason the request was made. As a result, data visibility control platform **140** may prevent the request from accessing the record.

Data owner device **110** may also grant access to data owner's patient records to the new medical provider. At any time, data owner may choose to grant, revoke, deny (e.g., reject), or restrict access (such as changing access rights from read and edit to read only). This de-centralizes the access to data owners' records by giving them direct control of the visibility of their records (the contents of which are encrypted and thus are not visible to data intermediary **150**). Data owners do not have to communicate to data intermediary **150** their desire to change data visibility and consent to access their records. Data intermediary **150** may still have privacy and security protocols for managing and storing data (with encryption layers implemented by data intermediary **150** in addition to the ones described).

Data owner device **110** may also be able to modify data at data intermediary **150**. In some embodiments, data owner device **110** may add information to records created by data consumer device **120**. For example, a record created by data consumer device **120** may include a section listing exercise or nutrition information linked to the data owner. Here, data owner device **110** may access the record and input updated exercise and/or nutrition information. Data owner device **110** may change information in records created by data consumer device **120**. For example, data consumer device **120** may have created a record and included an incorrect address or date of birth for the data owner. In response, data owner device **110** may access the record and correct the information. In some embodiments, data owner device **110** may delete part of a record, or an entire record.

Data intermediary **150** may authenticate the data owner attempting to modify the record prior to allowing the operation. For example, the data may be required to submit a password, biometric input, or any other form of authentication via data owner device **110** to data intermediary **150**. In some embodiments, the data owner may be required to perform multi-factor authentication such as inputting a password, and then entering a code sent to a phone number or email associated with data owner device **110**. In some embodiments, the request may be authenticated by the data owner providing a digital signature. For example, the data owner may use their private key (e.g., data owner private key **230**) to digitally sign and authenticate the request. Once authenticated, data intermediary **150** may perform the requested action. In some embodiments, all modifications may require authentication. In other embodiments, data intermediary **150** may be configured to require authentication for certain actions. For example, data intermediary **150** may require authentication when data owner device **110** attempts to delete part of, or an entire record.

In some embodiments, cryptographic hashes may be used to track changes through different versions of a record. When a record is being edited, a hash of the current version of the record may be computed or the previously computed hash of the current version of the record may be retrieved. As discussed above, data intermediary **150** may store a cryptographic hash of each record in association with the encrypted record, such as cryptographic hash **222.1** associated with encrypted record **220C.1** of FIG. **3**B. As shown in FIG. **3**A, the cryptographic hash may also be stored on the blockchain (e.g., blockchain platform **250**). When the record is edited, the hash of the current version of the record (that is, the version of the record that is to be edited) may be appended to, or embedded within, the edited version of the record. As a result, each new version of a record may include a hash of the immediately previous version of the record, creating a sequential linking of versions of the record. For example, a data owner may use data owner device **110** to edit a record. In doing so, the data owner may compute or retrieve the hash of the current version of the record and create the edited version of the record to which the hash is appended or embedded within. The data owner device **110** will then apply the procedure outlined in FIG. **2**C to the edited version of the record. The data consumer may follow the same procedure (once authorized by the data owner) to edit a record.

Data owner device **110** may also manage record access based on record versions. For example, data owner device **110** may grant access to the first version of a record to data consumer device **120**, but not the second version. This may be useful if the record owner, wishes to grant two parties partial access to the record. For example, the first record version may be created by the record owner's first medical provider. The record owner may subsequently switch providers. As a result, data owner device **110** associated with the record owner may generate a new version of the record. The new version may be associated with a new hash value. Data owner device **110** may then limit the first provider's access to the first version by associating their access with the first version's hash value. Additionally, data owner device **110** may grant the new provider access to the second version of the record by linking the new provider's access with the second version's hash value. In some embodiments, the hash may be cryptographic hash **222**. For example, document level access registry **520** may store key value pairs, where the key is cryptographic hash **222** corresponding to a record version, and the value is the entity (e.g., data consumer device **120**) with access to that version of the record.

Data visibility control platform **140** may be accessed via a web browser, hybrid or native web application, and/or application programming interface (API), etc., which is accessible by data owner device **110** and/or data consumer device **120**. Data visibility control platform **140** may provide a graphical user interface (GUI) via front-end **142** that allows data owner device **110** to, in real-time, quickly and clearly grant, deny, and revoke access to requesters.

FIGS. **6A**-**6B** depict a flowchart illustrating a method **600** for record-level encryption for a newly generated record from the point-of-view of data owner device **110**, according to some embodiments. Method **600** shall be described with reference to FIGS. **1**, **2A**, **2B**, **2C**, **4A**, **4B**, and **4C**; however, method **600** is not limited to that example embodiment.

In an embodiment, data owner device **110**, data consumer device **120**, data visibility control platform **140**, and/or data intermediary **150** may utilize method **600** to provide record-level encryption for records of data owner or newly generated records. Records may be managed by data intermediary **150** and stored in record database **160**. The record-level encryption described in method **600** may allow a data owner to have direct control over the visibility of their records, while allowing data intermediary **150** and/or record database **160** to manage security and privacy protocols. The foregoing description will describe an embodiment of the execution of method **600** with respect to data owner device **110**, data consumer device **120**, data visibility control platform **140**, data intermediary **150**, and/or record database **160**. While method **600** is described with reference to data visibility control platform **140**, method **600** may be executed on any computing device, such as, for example, the computer system described with reference to FIG. **8** and/or processing logic that may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, etc.), software (e.g., instructions that are stored in non-transitory computer-readable memory and that are executable using one or more processing devices), or a combination thereof.

It is to be appreciated that not all steps may be needed to perform the disclosure provided herein. Further, some of the steps may be performed simultaneously, or in a different order than shown in FIGS. **6A**-**6B**, as will be understood by a person of ordinary skill in the art.

At **610**, the data owner and the data consumer may generate public-private key pairs and may exchange public keys. As explained above, public keys may be exchanged by direct messages, broadcast messages, publishing the keys to a public forum or website, etc. In one example, data owner device **110** may use the user interface of front-end **142** to transmit data owner public key **210** to data consumer device **120**, and vice versa. Data owner device **110** may use back-end processor **144**, key generating service **146**, and entropy source **148** of data visibility control platform **140** to generate data owner public key **210** and data owner private key **230**. Similarly, data consumer device **120** may use back-end processor **144**, key generating service **146**, and entropy source **148** of data visibility control platform **140**.

As described in FIGS. **2A**-**2C**, data consumer device **120** may generate a record comprising data of the data owner. In some embodiments, a record may be a file in a computer readable format or another form of electronically stored data. Data consumer device **120** may encrypt the record using data owner public key **210**.

At **620**, data owner device **110** may receive the record that is encrypted using the data owner's public key, such as data owner public key **210** of FIG. **2A**. In some embodiments, data owner device **110** may receive the encrypted record from data intermediary **150**.

In some embodiments, data consumer device **120** may upload the record encrypted with data owner public key **210** to data intermediary **150** via network **130**. Data intermediary **150** may transmit the encrypted record to data owner device **110**. In some embodiments, data consumer device **120** may use data visibility control platform **140** to upload the encrypted record to data intermediary **150** and data visibility control platform **140** may also transmit the encrypted record to data owner device **110**.

At **630**, the data owner may decrypt the encrypted record using the data owner's private key, such as data owner private key **230** of FIG. **2A**. Data owner device **110** may use data owner private key **230** to perform this decryption locally using hardware and/or software on data owner device **110** or may use the back-end processor **144** and/or key generating service **146** to decrypt the encrypted record with data owner private key **230**. The data owner may also generate a cryptographic hash of the record, which may be used for future authentication of the record.

At **640**, the data owner generates a record key associated with the record. Data owner device **110** may generate record keys, such as record key **240A** of FIG. **2C**, locally using hardware and/or software on data owner device **110** or may use back-end processor **144**, key generating service **146**, and/or entropy source **148** of data visibility control platform **140** to generate record keys. The data owner may generate a record key for each record of the data owner. In some embodiments, the data owner may also generate a new record key each time a record is edited and repeat the process described with reference to FIG. **2A**-**2C** to upload a new encrypted record containing the edits, while data intermediary **150** stores each version of the record.

At **650**, the data owner encrypts the record comprising data corresponding to the data owner using the record key. In some embodiments, data owner device **110** may use back-end processor **144** and/or key generating service **146** provided by data visibility control platform **140** to encrypt the record with record key **240A**, e.g., the record key.

At **660**, the data owner encrypts the record key using the public key of the data owner, such as data owner public key **210** of FIG. **2C**, to generate an encrypted record key, such as encrypted record key **240B** of FIG. **2C**. In some embodiments, data owner device **110** may encrypt record key with data owner public key **210** locally using hardware and/or software on data owner device **110** or may encrypt the record key via back-end processor **144** and/or key generating service **146** provided by data visibility control platform **140**.

At **670**, the data owner may store the encrypted record key and a cryptographic hash (e.g., cryptographic hash **222**) of the record in a blockchain. In some embodiments, data owner device **110** may propagate encrypted record key **240B** to blockchain platform **250**. Data owner may further store an identifier corresponding to the public-private key pair (e.g., data owner public key **210** and data owner private key **230**). The identifier may be key identifier **224**.

At **680**, the data owner may receive a transaction ID corresponding to the encrypted record key, wherein the transaction ID is generated when encrypted record key is stored on a blockchain. More specifically, the blockchain may generate the transaction ID and store the transaction ID, the encrypted record key, and a cryptographic hash of the record in a block of the blockchain.

At **690**, the data owner transmits at least the transaction ID and encrypted record to the data intermediary, which stores them in the records database. In some embodiments, a data owner storage service may also record that transaction ID **260** is associated with encrypted record key **240B** and record key **240A**. In some embodiments, there may be a plurality of records associated with the data owner. Therefore, there may be a plurality of record keys **240A**, corresponding encrypted record keys **240B**, and corresponding transaction IDs **260**. A data owner storage service may store each transaction ID **260** and the associated record identification, record keys **240**A, and/or encrypted record keys **240**B.

In some embodiments, data owner device may transmit the encrypted record, encrypted with record key **240**A, to data intermediary **150**. Data intermediary **150** may use record database **160** to store the encrypted record.

FIG. **7** depicts a process flow diagram illustrating a method **700** for record-level encryption for reading and/or editing a record. Method **700** shall be described with reference to FIGS. **1**, **2**A, **2**B, **2**C, **4**A, **4**B, and **4**C; however, method **700** is not limited to that example embodiment.

In an embodiment, data visibility control platform **140** may utilize method **700** to provide record-level encryption for records of data owner for accessing records of a data owner. In some embodiments, records that are accessed may be edited and stored as a new encrypted record, data owner device **110** and data consumer device **120** may utilize FIGS. **2**A-**2**C and FIG. **6**A-**6**B to store newly generated, encrypted records. Encrypted records may be managed by data intermediary **150** and stored in record database **160**. The record-level encryption described in method **700** may allow a data owner to have direct control over the visibility of their records, while allowing data intermediary **150** and/or record database **160** to manage security and privacy protocols. In some embodiments, the data consumer discussed in method **700** may be the party that generated the record (e.g., the data consumer described in FIG. **6**) or may be a different party. For example, a health care professional may generate a record for a patient's file after a visit. The healthcare professional may use method **600** to generate the file. A different data consumer, e.g., a health insurance provider, may need to access the data owner's record generated by the healthcare professional. The method described in FIG. **7** may be used by any data consumer who has been given access to view the data owner's records to request access to a specific record and receive that record from the data intermediary. While method **700** is described with reference to data visibility control platform **140**, method **700** may be executed on any computing device, such as, for example, the computer system **800** described with reference to FIG. **8** and/or processing logic that may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, etc.), software (e.g., instructions executing on a processing device), or a combination thereof.

It is to be appreciated that not all steps may be needed to perform the disclosure provided herein. Further, some of the steps may be performed simultaneously, or in a different order than shown in FIG. **7**, as will be understood by a person of ordinary skill in the art.

At **710**, data consumer device **120** may generate a request. The request may comprise a message indicating the data consumer wants to access an encrypted record of the data owner stored in record database **160**. The request may identify an encrypted record with the transaction ID (e.g., transaction ID **260**.) The request may also include identifying information of data consumer device **120** and/or the data owner as well as the purpose of use for the encrypted record and its data to allow the data consumer to evaluate whether the request should be granted. For example, this could include identifying information of the data consumer and/or data consumer device **120**, a timestamp associated with the request, and/or a digital signature added to the encrypted request, to name a few non-limiting examples. In some embodiments, data consumer device **120** may encrypt the request using data owner public key **210**. As explained above, public keys may be exchanged by direct messages, broadcast messages, publishing the keys to a public forum or website, etc.

Data consumer device **120** may transmit the encrypted request to data owner device **110** via data intermediary **150**. In one example, data consumer device **120** may use the user interface of front-end **142** to transmit the request to data owner device **110**. Data consumer device **120** may also transmit the encrypted request to the data owner via a network, without routing the request through the data intermediary **150**.

At **720**, data owner device **110** may receive the request generated by data consumer device **120**. In some embodiments, data owner device **110** may receive the encrypted request from data intermediary **150** via network **130**. Data owner device **110** may decrypt the encrypted request. Data owner device **110** may decrypt the encrypted request including transaction ID using the data owner private key. As described above, the encrypted record key used to decrypt the encrypted record stored in record database **160** is stored on blockchain platform **250**. The encrypted record key may be identified and retrieved by data owner device **110** using transaction ID **260** identified in the request. For example, the request may identify transaction ID **260.1**, which corresponds to encrypted record **220**C.**1** and record key **240**A.**1**. Record key **240**A.**1** may be stored on blockchain platform as encrypted record key **240**B.**1**.

At **730**, data owner device **110** may request the encrypted record key from blockchain platform **250**. Data owner device **110** may identify the encrypted record key using the corresponding transaction ID identified in the request from data consumer device **120**. As described above, when the encrypted record is generated, as described in FIG. **6** using method **600**, the record stored in record database **160** is encrypted using a record key. The record key is encrypted using the data owner's public key and stored via blockchain platform **250**.

At **740**, data owner device **110** may receive the encrypted key from blockchain platform **250**. Data owner device **110** may also receive the cryptographic hash of the record from blockchain platform **250**. The cryptographic hash may be cryptographic hash **222**. Data owner device **110** may further receive the key identifier from blockchain platform **250**. The key identifier may be key identifier **224**. Data owner device **110** may use the data owner private key to decrypt the encrypted record key. For example, data owner device **110** may use data owner private key **230** to decrypt encrypted record key **240**B to retrieve record key **240**A. Data owner device **110** may determine that data owner private key **230** is capable of decrypting encrypted record key **240**B based on key identifier **224**. For example, data owner device **110** may include a lookup table or other data structure linking key identifier **224** to data owner public key **210** and data owner private key **230**. In order for data consumer device **120** to access the encrypted record, data owner device may transmit the record key to data consumer device **120**. To securely transmit the record key, data owner device **110** may encrypt the record key using the data consumer public key. As explained above, public keys may be exchanged by direct messages, broadcast messages, publishing the keys to a public forum or website, etc. For example, data owner device **110** may encrypt record key **240**A using data consumer public key **420**. Encrypted record key **430** may be encrypted using data consumer public key **420**.

At **750**, data owner device **110** may transmit the encrypted record key to data consumer device **120** via data intermediary **150**. In some embodiments, data owner device **110** may include a digital signature with encrypted record key **430**. This may allow data intermediary **150** and/or back-end processor **144** of data visibility platform **140** to verify the data owner's identity. The data owner device **110** may use front-end **142** of data visibility control platform **140** to transmit the encrypted record key to data consumer vice **120** via data intermediary **150**. Included with the encrypted record key may also be a request to retrieve the encrypted record for data consumer device **120**. The encrypted record may be identified using the transaction ID that was identified in the request sent to data owner device **110** at **710**.

At **760**, data intermediary receives the encrypted record key and request to retrieve the encrypted record from record database **160** from data owner device **110**. Data intermediary **150** may retrieve the encrypted record from record database **160**. For example, data intermediary may retrieve encrypted record **220**C.**1** based on the included transaction ID **260.1**.

At **770**, data consumer device **120** may receive the encrypted record key and encrypted record from data intermediary **150**. Data consumer device **120** may decrypt the encrypted record key using the data consumer private key to obtain the record key. Data consumer device **120** may then use the record key to decrypt the encrypted record and obtain the record corresponding to the transaction ID identified in the request from data consumer device **120** at **710**. For example, data consumer device **120** may decrypt encrypted record key **430** using data consumer private key **440** to obtain record key **240**A. Data consumer device **120** can also use the digital signature, when present, to confirm that the record key was provided by the data owner. Data consumer device **120** may decrypt encrypted record **220**C using corresponding record key **240**A to obtain the plaintext of the record identified in the request.

Various embodiments may be implemented, for example, using one or more computer systems, such as computer system **800** shown in FIG. **8**. One or more computer systems **800** may be used, for example, to implement any of the embodiments discussed herein, as well as combinations and sub-combinations thereof.

Computer system **800** may include one or more processors (also called central processing units, or CPUs), such as a processor **804**. Processor **804** may be connected to a bus or communication infrastructure **806**.

Computer system **800** may also include user input/output device(s) **803**, such as monitors, keyboards, pointing devices, etc., which may communicate with communication infrastructure **806** through user input/output interface(s) **802**.

One or more of processors **804** may be a graphics processing unit (GPU). In an embodiment, a GPU may be a processor that is a specialized electronic circuit designed to process mathematically intensive applications. With capabilities of general-purpose computing on graphics processing units (GPGPU), the GPU may be useful in various other applications. The GPU may have a parallel structure that is efficient for parallel processing of large blocks of data, such as mathematically intensive data common to computer graphics applications, images, videos, vector processing, array processing, etc., as well as cryptography (including brute-force cracking), generating cryptographic hashes or hash sequences, solving partial hash-inversion problems, and/or producing results of other proof-of-work computations for some blockchain-based applications, for example.

Computer system **800** may also include a main or primary memory **808**, such as random access memory (RAM). Main memory **808** may include one or more levels of cache. Main memory **808** may have stored therein control logic (i.e., computer software) and/or data.

Computer system **800** may also include one or more secondary storage devices or memory **810**. Secondary memory **810** may include, for example, a hard disk drive **812** and/or a removable storage device or drive **814**. Removable storage drive **814** may be a floppy disk drive, a magnetic tape drive, a compact disk drive, an optical storage device, tape backup device, and/or any other storage device/drive.

Removable storage drive **814** may interact with a removable storage unit **818**. Removable storage unit **818** may include a computer usable or readable storage device having stored thereon computer software (control logic) and/or data. Removable storage unit **818** may be a floppy disk, magnetic tape, compact disk, DVD, optical storage disk, and/any other computer data storage device. Removable storage drive **814** may read from and/or write to removable storage unit **818**.

Secondary memory **810** may include other means, devices, components, instrumentalities or other approaches for allowing computer programs and/or other instructions and/or data to be accessed by computer system **800**. Such means, devices, components, instrumentalities or other approaches may include, for example, a removable storage unit **822** and an interface **820**. Examples of the removable storage unit **822** and the interface **820** may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM or PROM) and associated socket, a memory stick and USB port, a memory card and associated memory card slot, and/or any other removable storage unit and associated interface.

Computer system **800** may further include a communication or network interface **824**. Communication interface **824** may enable computer system **800** to communicate and interact with any combination of external devices, external networks, external entities, etc. (individually and collectively referenced by reference number **828**). For example, communication interface **824** may allow computer system **800** to communicate with external or remote devices **828** over communications path **826**, which may be wired and/or wireless (or a combination thereof), and which may include any combination of LANs, WANs, the Internet, etc. Control logic and/or data may be transmitted to and from computer system **800** via communication path **826**.

Computer system **800** may also be any of a personal digital assistant (PDA), desktop workstation, laptop or notebook computer, netbook, tablet, smart phone, smart watch or other wearable, appliance, part of the Internet-of-Things, and/or embedded system, to name a few non-limiting examples, or any combination thereof.

Computer system **800** may be a client or server, accessing or hosting any applications and/or data through any delivery paradigm, including but not limited to remote or distributed cloud computing solutions; local or on-premises software ("on-premise" cloud-based solutions); "as a service" models (e.g., content as a service (CaaS), digital content as a service (DCaaS), software as a service (SaaS), managed software as a service (MSaaS), platform as a service (PaaS), desktop as a service (DaaS), framework as a service (FaaS), backend as a service (BaaS), mobile backend as a service (MBaaS), infrastructure as a service (IaaS), etc.); and/or a hybrid model including any combination of the foregoing examples or other services or delivery paradigms.

Any applicable data structures, file formats, and schemas in computer system **900** may be derived from standards including but not limited to JavaScript Object Notation

(JSON), Extensible Markup Language (XML), Yet Another Markup Language (YAML), Extensible Hypertext Markup Language (XHTML), Wireless Markup Language (WML), MessagePack, XML User Interface Language (XUL), or any other functionally similar representations alone or in combination. Alternatively, proprietary data structures, formats or schemas may be used, either exclusively or in combination with known or open standards.

In some embodiments, a tangible, non-transitory apparatus or article of manufacture comprising a tangible, non-transitory computer useable or readable medium having control logic (software) stored thereon may also be referred to herein as a computer program product or program storage device. This includes, but is not limited to, computer system **800**, main memory **808**, secondary memory **810**, and removable storage units **818** and **822**, as well as tangible articles of manufacture embodying any combination of the foregoing. Such control logic, when executed by one or more data processing devices (such as computer system **800**), may cause such data processing devices to operate as described herein.

Based on the teachings contained in this disclosure, it will be apparent to persons skilled in the relevant art(s) how to make and use embodiments of this disclosure using data processing devices, computer systems and/or computer architectures other than that shown in FIG. **8**. In particular, embodiments may operate with software, hardware, and/or operating system implementations other than those described herein.

It is to be appreciated that the Detailed Description section, and not any other section, is intended to be used to interpret the claims. Other sections may set forth one or more but not all example embodiments as contemplated by the inventor(s), and thus, are not intended to limit this disclosure or the appended claims in any way.

While this disclosure describes example embodiments for example fields and applications, it should be understood that the disclosure is not limited thereto. Other embodiments and modifications thereto are possible, and are within the scope and spirit of this disclosure. For example, and without limiting the generality of this paragraph, embodiments are not limited to the software, hardware, firmware, and/or entities illustrated in the figures and/or described herein. Further, embodiments (whether or not explicitly described herein) have significant utility to fields and applications beyond the examples described herein.

Embodiments have been described herein with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries may be defined as long as the specified functions and relationships (or equivalents thereof) are appropriately performed. Also, alternative embodiments may perform functional blocks, steps, operations, methods, etc. using orderings different than those described herein.

References herein to "one embodiment," "an embodiment," "an example embodiment," "some embodiments," or similar phrases, indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it would be within the knowledge of persons skilled in the relevant art(s) to incorporate such feature, structure, or characteristic into other embodiments whether or not explicitly mentioned or described herein.

Additionally, some embodiments can be described using the expression "coupled" and "connected" along with their derivatives. These terms are not necessarily intended as synonyms for each other. For example, some embodiments can be described using the terms "connected" and/or "coupled" to indicate that two or more elements are in direct physical or electrical contact with each other. The term "coupled," however, can also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

The breadth and scope of this disclosure should not be limited by any of the above-described example embodiments, but should be defined only in accordance with the following claims and their equivalents.

We claim:

1. A method comprising:

generating, by a data owner device of a data owner, a first key identifier corresponding to a first public-private key pair of the data owner, wherein the first public-private key pair comprises a first public key of the data owner and a first private key of the data owner;

generating, by the data owner device, a second key identifier corresponding to a second public-private key pair of the data owner, wherein the second public-private key pair comprises a second public key of the data owner and a second private key of the data owner;

receiving, at the data owner device via a communications network, a record comprising data of the data owner, wherein the record is encrypted using the first public key of the data owner;

decrypting, by the data owner device, the record using the first private key of the data owner;

generating, by the data owner device, a record key;

encrypting, by the data owner device, the record using the record key;

encrypting, by the data owner device, the record key using the first private key of the data owner;

providing, by the data owner device via the communications network, the encrypted record key and the first key identifier to a storage device for storage, wherein the storage device is remote from the data owner device;

receiving, by the data owner device via the communications network, a transaction identification corresponding to the encrypted record key and the first key identifier, wherein the transaction identification is generated when the encrypted record key and the first key identifier are stored on the storage device;

providing, by the data owner device via the communications network, the record encrypted with the record key to a data intermediary for storage at the data intermediary, wherein the data intermediary is remote from the data owner device and the storage device;

receiving, by the data owner device via the communications network, a request from a data consumer to access the record, wherein the request comprises at least the transaction identification and the request is encrypted with the second public key of the data owner;

decrypting, by the data owner device, the request using the second private key of the data owner;

retrieving, by the data owner device from the storage device via the communications network, the encrypted record key corresponding to the transaction identification;

decrypting, by the data owner device, the encrypted record key using the first private key, wherein the data owner device identifies the first private key based on the first key identifier associated with the transaction identification;

encrypting, by the data owner device, the record key using a public key of the data consumer; and

transmitting, by the data owner device via the communications network, the record key encrypted using the public key of the data consumer to a data consumer device.

2. The method of claim **1**, further comprising:

receiving, by the data owner device via the communications network, a second request to access the record from the data consumer device, wherein the second request comprises the transaction identification and the second request is encrypted with the first public key of the data owner;

decrypting, by the data owner device, the second request to obtain the transaction identification using the first private key; and

retrieving, by the data owner device from the storage device via the communications network, the encrypted record key corresponding to the transaction identification.

3. The method of claim **2**, further comprising:

decrypting, by the data owner device, the encrypted record key using the first private key, wherein the data owner device identifies the first private key based on the first key identifier;

encrypting, by the data owner device, the record key using the public key of the data consumer; and

transmitting, by the data owner device via the communications network, the record key encrypted using the public key of the data consumer to the data consumer.

4. The method of claim **3**, further comprising:

applying a digital signature, by the data owner device, to the record key encrypted using the data consumer public key before transmitting the record key encrypted using the data consumer public key to the data consumer.

5. The method of claim **2**, further comprising: denying access to the record, by the data owner device, based at least on a time the second request was generated or an identity of the data consumer.

6. The method of claim **2**, wherein the data owner is a patient and the data consumer is a medical provider.

7. The method of claim **1**, wherein prior to encrypting the record using the record key, the method further comprises generating, by the data owner device, a cryptographic hash of the record.

8. The method of claim **7**, further comprising:

providing, by the data owner device via the communications network, the the cryptographic hash to the storage device for storage in association with the record key and the transaction identification.

9. A non-transitory computer-readable memory having instructions stored thereon that, when executed by at least one computing device, cause the at least one computing device to perform operations comprising:

generating, by a data owner device of a data owner, a first key identifier corresponding to a first public-private key pair of the data owner, wherein the first public-private key pair comprises a first public key of the data owner and a first private key of the data owner;

generating, by the data owner device, a second key identifier corresponding to a second public-private key pair of the data owner, wherein the second public-private key pair comprises a second public key of the data owner and a second private key of the data owner;

receiving, at the data owner device via a communications network, a record comprising data of the data owner, wherein the record is encrypted using the first public key of the data owner;

decrypting, by the data owner device, the record using the first private key of the data owner;

generating, by the data owner device, a record key;

encrypting, by the data owner device, the record using the record key;

encrypting, by the data owner device, the record key using the first private key of the data owner;

providing, by the data owner device via the communications network, the encrypted record key and the first key identifier to a storage device for storage on the storage device, wherein the storage device is remote from the data owner device;

receiving, by the data owner device via the communications network, a transaction identification corresponding to the encrypted record key and the first key identifier, wherein the transaction identification is generated when the encrypted record key and the first key identifier are stored on the storage device;

providing, by the data owner device via the communications network, the record encrypted with the record key to a data intermediary for storage at the data intermediary, wherein the data intermediary is remote from the data owner device and the storage device;

receiving, by the data owner device via the communications network, a request from a data consumer to access the record, wherein the request comprises at least the transaction identification and the request is encrypted with the second public key of the data owner;

decrypting, by the data owner device, the request using the second private key of the data owner;

retrieving, by the data owner device from the storage device via the communications network, the encrypted record key corresponding to the transaction identification;

decrypting, by the data owner device, the encrypted record key using the first private key, wherein the data owner device identifies the first private key based on the first key identifier associated with the transaction identification;

encrypting, by the data owner device, the record key using a public key of the data consumer; and

transmitting, by the data owner device via the communications network, the record key encrypted using the public key of the data consumer to a data consumer device.

10. The non-transitory computer-readable memory of **9**, wherein the operations further comprise:

receiving, by the data owner device via the communications network, a second request to access the record from the data consumer device, wherein the second request comprises the transaction identification and the second request is encrypted with the first public key of the data owner;

decrypting, by the data owner device, the second request to obtain the transaction identification using the first private key; and

retrieving, by the data owner device from the storage device via the communications network, the encrypted record key corresponding to the transaction identification.

11. The non-transitory computer-readable memory of claim **10**, wherein the operations further comprise:

decrypting, by the data owner device, the encrypted record key using the first private key, wherein the data owner device identifies the first private key based on the first key identifier;

encrypting, by the data owner device, the record key using the public key of the data consumer; and

transmitting, by the data owner device via the communications network, the record key encrypted using the public key of the data consumer to the data consumer.

12. The non-transitory computer-readable memory claim **11**, wherein the operations further comprise:

applying a digital signature, by the data owner device, to the record key encrypted using the data consumer public key before transmitting the record key encrypted using the data consumer public key to the data consumer.

13. The non-transitory computer-readable memory of claim **10**, wherein the operations further comprise: denying access to the record, by the data owner device, based at least on a time the second request was generated or an identity of the data consumer.

14. The non-transitory computer-readable memory of claim **10**, wherein the data owner is a patient and the data consumer is a medical provider.

15. The non-transitory computer-readable memory of claim **9**, wherein prior to encrypting the record using the record key, the operations further comprise generating, by the data owner device, a cryptographic hash of the record.

16. The non-transitory computer-readable memory of claim **15**, wherein the operations further comprise:

providing, by the data owner device via the communications network, the cryptographic hash to the storage device for storage in association with the record key and the transaction identification.

17. A system comprising:

a memory; and

at least one processor coupled to the memory and configured to:

generate a first key identifier corresponding to a first public-private key pair of a data owner, wherein the first public-private key pair comprises a first public key of the data owner and a first private key of the data owner;

generate a second key identifier corresponding to a second public-private key pair of the data owner, wherein the second public-private key pair comprises a second public key of the data owner and a second private key of the data owner;

receive, via a communications network, a record comprising data of the data owner, wherein the record is encrypted using the first public key of the data owner;

decrypt the record using the first private key of the data owner;

generate a record key;

encrypt the record using the record key;

encrypt the record key using the first private key of the data owner;

provide, via the communications network, the encrypted record key and the first key identifier to a storage device for storage, wherein the storage device is remote from the system;

receive, via the communications network, a transaction identification corresponding to the encrypted record key and the first key identifier, wherein the transaction identification is generated when the encrypted record key and the first key identifier are stored on the storage device;

provide, via the communications network, the record encrypted with the record key to a data intermediary for storage at the data intermediary, wherein the data intermediary is remote from the system and the storage device;

receive, via the communications network, a request from a data consumer to access the record, wherein the request comprises at least the transaction identification and the request is encrypted with the second public key of the data owner;

decrypt the request using the second private key of the data owner;

retrieve, from the storage device via the communications network, the encrypted record key corresponding to the transaction identification;

decrypt the encrypted record key using the first private key, wherein the first private key is identified based on the first key identifier associated with the transaction identification;

encrypt the record key using a public key of the data consumer; and

transmit, via the communications network, the record key encrypted using the public key of the data consumer to a data consumer device.

18. The system of claim **17**, the at least one processor further configured to:

receive, via the communications network, a second request to access the record from the data consumer device, wherein the second request comprises the transaction identification and the second request is encrypted with the first public key of the data owner,

decrypt the second request to obtain the transaction identification using the first private key; and

retrieve, from the storage device via the communications network, the encrypted record key corresponding to the transaction identification.

19. The system of claim **18**, the at least one processor further configured to:

decrypt the encrypted record key using the first private key, wherein the first private key is identified based on the first key identifier;

encrypt the record key using the public key of the data consumer; and

transmit, via the communications network, the record key encrypted using the public key of the data consumer to the data consumer.

20. The system of claim **19**, the at least one processor further configured to:

apply a digital signature to the record key encrypted using the data consumer public key before transmitting the record key encrypted using the data consumer public key to the data consumer.

21. The system of claim **18**, the at least one processor further configured to:

deny access to the record based at least on a time the second request was generated or an identity of the data consumer.

22. The system of claim **18**, wherein the data owner is a patient and the data consumer is a medical provider.

23. The system of claim **17**, wherein prior to encrypting the record using the record key, the at least one processor further configured to: generate, by the data owner device, a cryptographic hash of the record.

24. The system of claim **23**, the at least one processor further configured to:

provide, via the communications network, the cryptographic hash to the storage device for storage in association with the record key and the transaction identification.

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