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Denning et al.

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(54) **SYSTEM AND METHOD FOR DELIVERING ENCRYPTED INFORMATION IN A COMMUNICATION NETWORK USING LOCATION IDENTITY AND KEY TABLES**

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(51) **Int. Cl.**

H04L 9/00	(2006.01)
H04K 1/00	(2006.01)

(52) **U.S. Cl.** **713/168**; 380/45; 380/258

(58) **Field of Classification Search** 380/255, 380/258, 45; 713/168, 201
See application file for complete search history.

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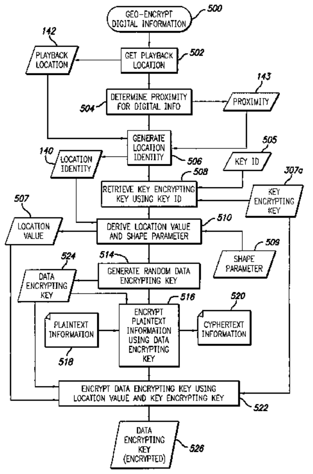
(57) **ABSTRACT**

Access to digital data is controlled by encrypting the data in such a manner that, in a single digital data acquisition step, it can be decrypted only at a specified location, within a specific time frame, and with a secret key. Data encrypted in such a manner is said to be geo-encrypted. This geo-encryption process comprises a method in which plaintext data is first encrypted using a data encrypting key that is generated at the time of encryption. The data encrypting key is then encrypted (or locked) using a key encrypting key and information derived from the location of the intended receiver. The encrypted data encrypting key is then transmitted to the receiver along with the ciphertext data. The receiver both must be at the correct location and must have a copy of the corresponding key decrypting key in order to derive the location information and decrypt the data encrypting key. After the data encrypting key is decrypted (or unlocked), it is used to decrypt the ciphertext. If an attempt is made to decrypt the data encrypting key at an incorrect location or using an incorrect secret key, the decryption will fail. If the sender so elects, access to digital data also can be controlled by encrypting it in such a manner that it must traverse a specific route from the sender to the recipient in order to enable decryption of the data. Key management can be handled using either private-key or public-key cryptography. If private-key cryptography is used, the sender can manage the secret key decrypting keys required for decryption in a secure manner that is transparent to the recipient. As a consequence of its ability to manipulate the secret keys, the sender of encrypted data retains the ability to control access to its plaintext even after its initial transmission.

48 Claims, 10 Drawing Sheets


GEO-ENCRYPT DIGITAL INFORMATION
500
142
PLAYBACK LOCATION
GET PLAYBACK LOCATION
502
143
DETERMINE PROXIMITY FOR DIGITAL INFO
504
PROXIMITY
GENERATE LOCATION IDENTITY
505
140
LOCATION IDENTITY
506
KEY ID
508
307a
RETRIEVE KEY ENCRYPTING KEY USING KEY ID
KEY ENCRYPTING KEY
507
LOCATION VALUE
DERIVE LOCATION VALUE AND SHAPE PARAMETER
510
509
524
514
SHAPE PARAMETER
DATA ENCRYPTING KEY
GENERATE RANDOM DATA ENCRYPTING KEY
516
520
PLAINTEXT INFORMATION
ENCRYPT PLAINTEXT INFORMATION USING DATA ENCRYPTING KEY
CYPHERTEXT INFORMATION
518
ENCRYPT DATA ENCRYPTING KEY USING LOCATION VALUE AND KEY ENCRYPTING KEY
522
DATA ENCRYPTING KEY (ENCRYPTED)
526

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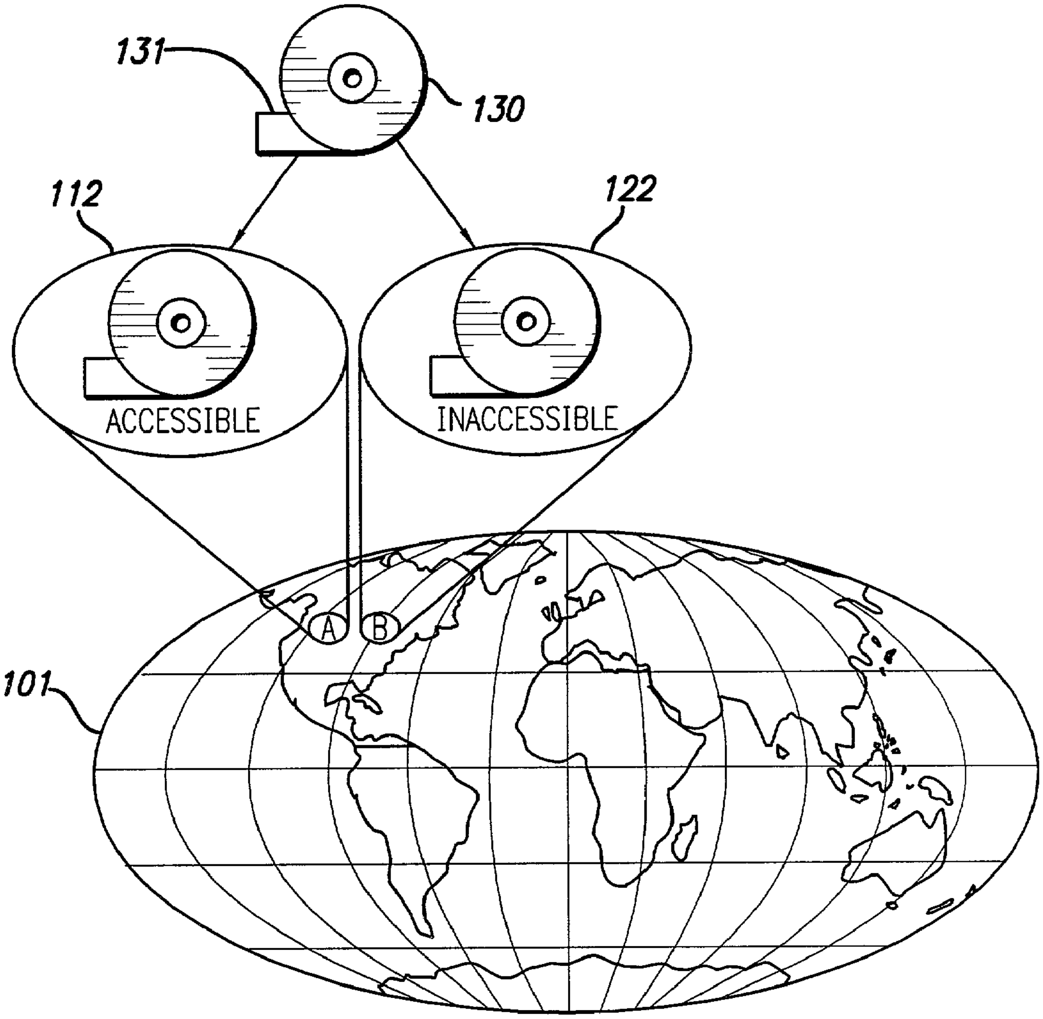

131
130
112
122
ACCESSIBLE
INACCESSIBLE
A
B
101

FIG. 1

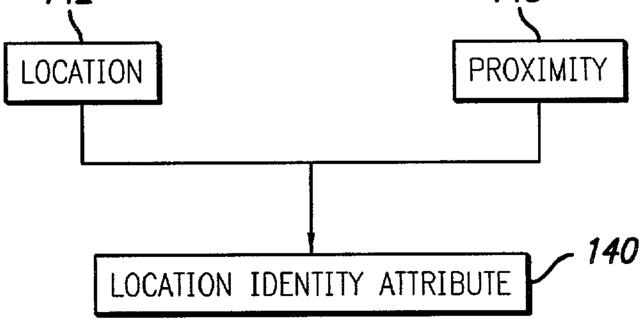

142
143
LOCATION
PROXIMITY
LOCATION IDENTITY ATTRIBUTE
140

FIG. 2

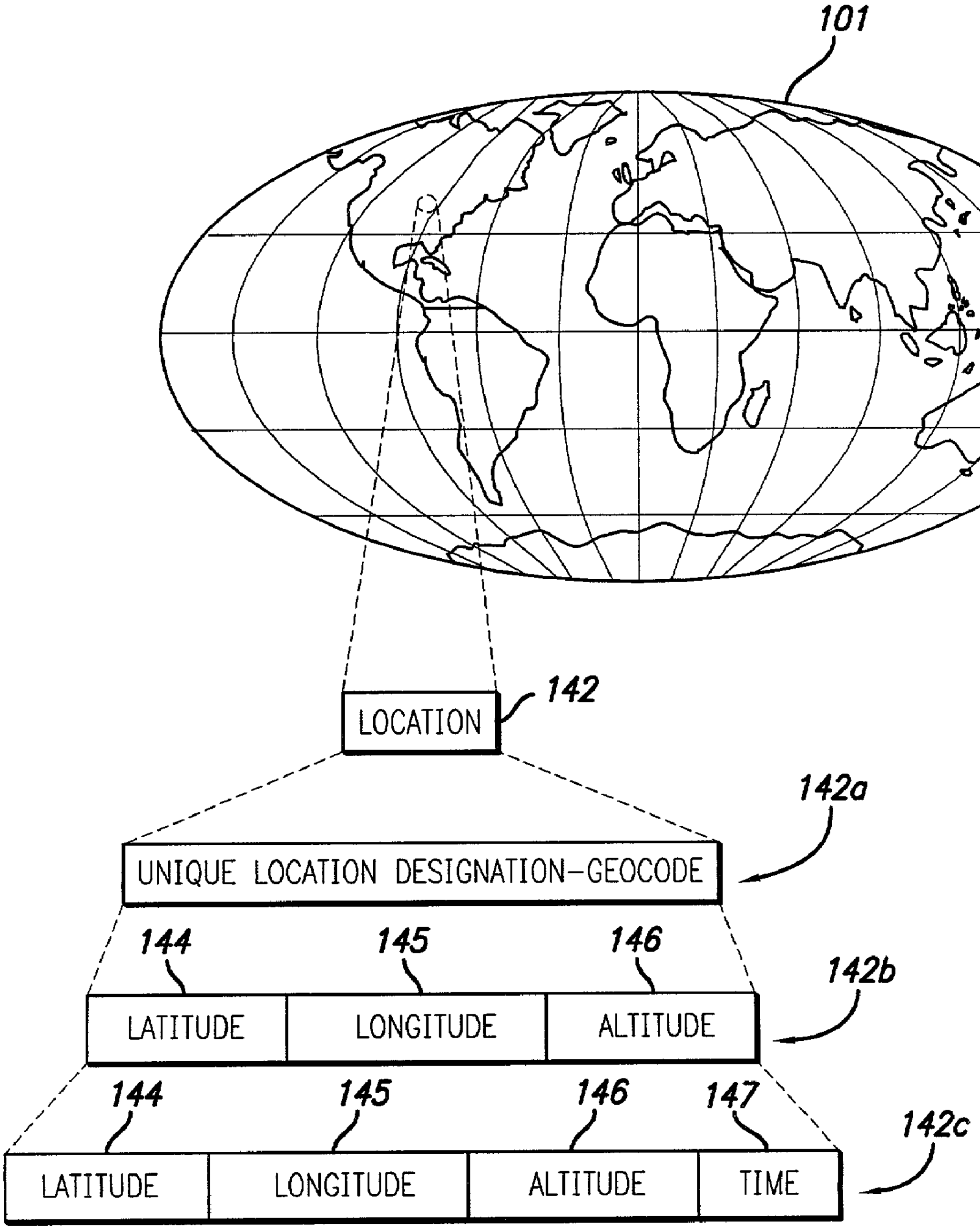

101
LOCATION
142
142a
UNIQUE LOCATION DESIGNATION-GEOCODE
144
145
146
142b
LATITUDE
LONGITUDE
ALTITUDE
144
145
146
147
142c
LATITUDE
LONGITUDE
ALTITUDE
TIME

FIG. 3

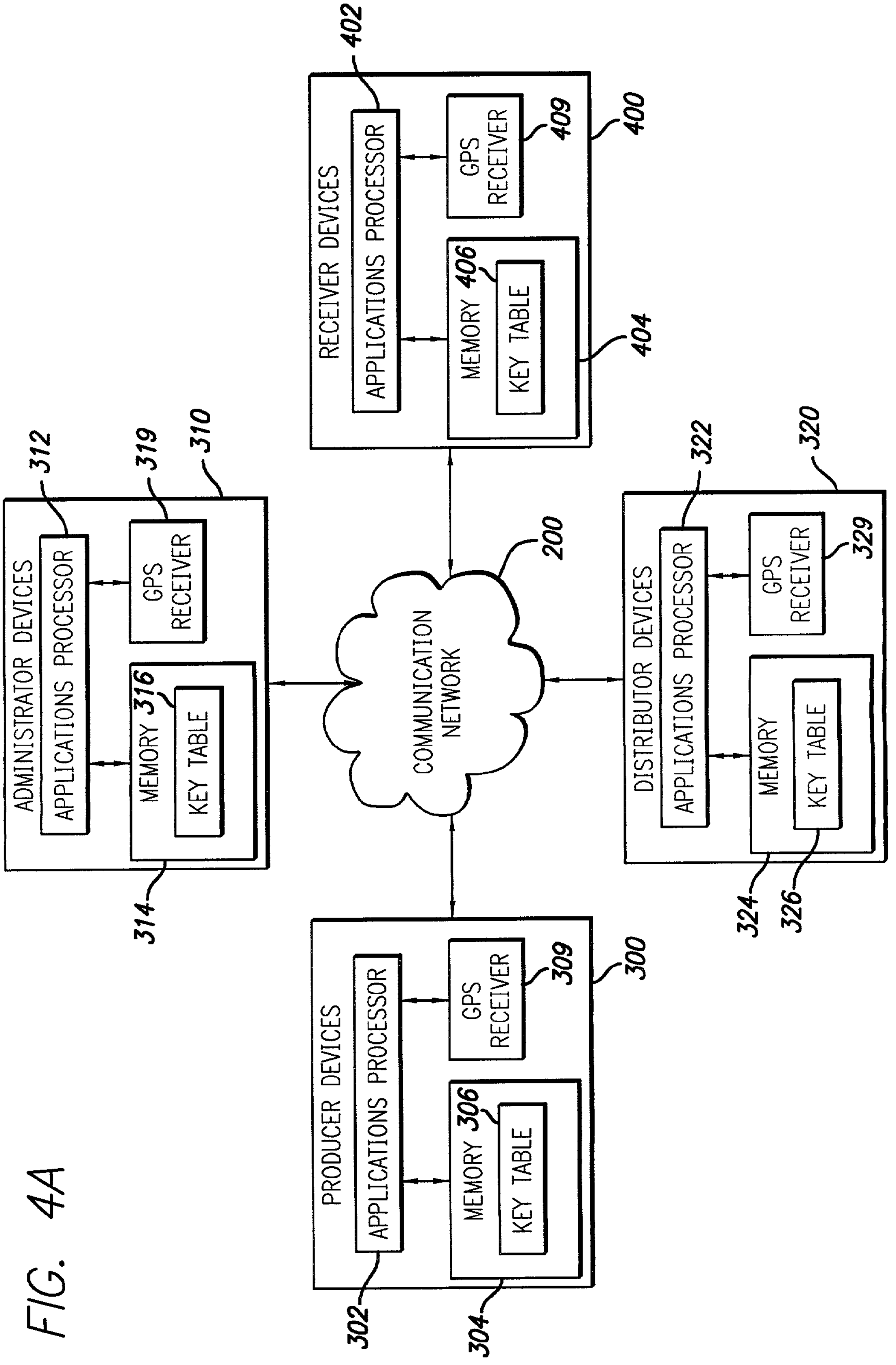

RECEIVER DEVICES
APPLICATIONS PROCESSOR
GPS RECEIVER
MEMORY
KEY TABLE
400
402
404
406
409
ADMINISTRATOR DEVICES
APPLICATIONS PROCESSOR
GPS RECEIVER
MEMORY
KEY TABLE
310
312
314
316
319
COMMUNICATION NETWORK
200
DISTRIBUTOR DEVICES
APPLICATIONS PROCESSOR
GPS RECEIVER
MEMORY
KEY TABLE
320
322
324
326
329
PRODUCER DEVICES
APPLICATIONS PROCESSOR
GPS RECEIVER
MEMORY
KEY TABLE
300
302
304
306
309

FIG. 4A

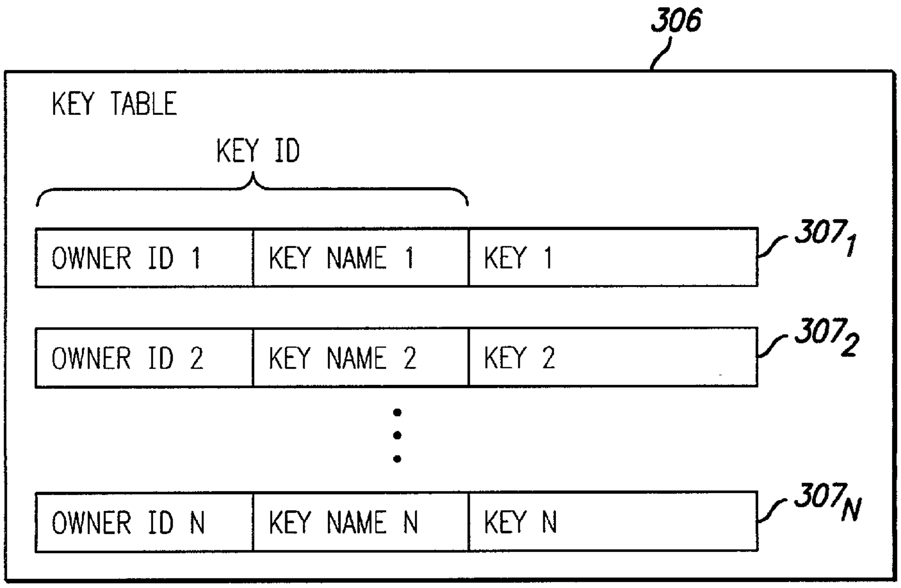

306
KEY TABLE
KEY ID
OWNER ID 1
KEY NAME 1
KEY 1
307_1
OWNER ID 2
KEY NAME 2
KEY 2
307_2
OWNER ID N
KEY NAME N
KEY N
307_N

FIG. 4B

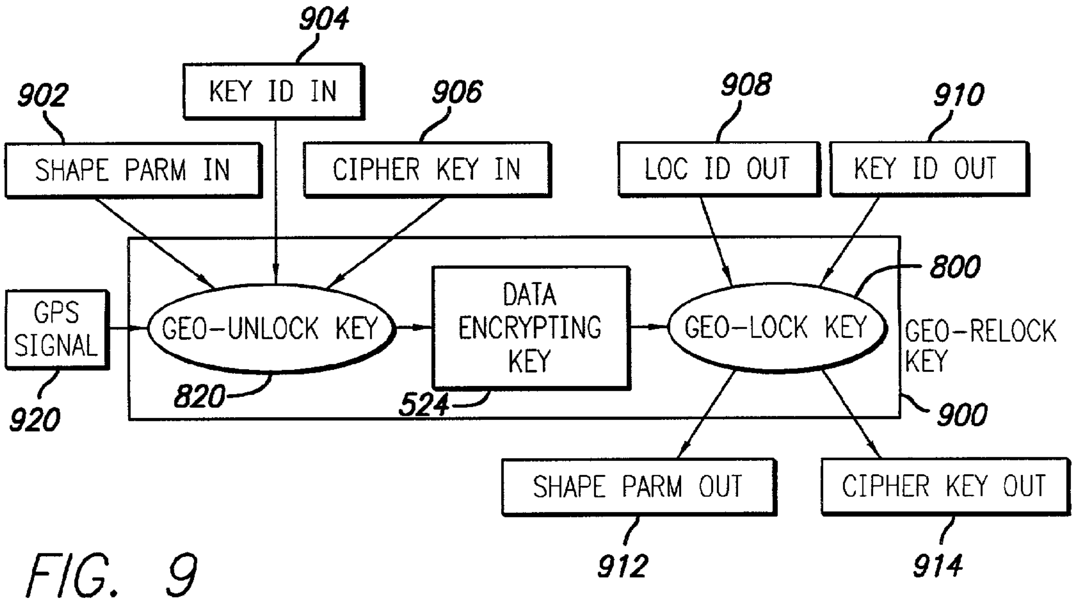

904
KEY ID IN
902
SHAPE PARM IN
906
CIPHER KEY IN
908
LOC ID OUT
910
KEY ID OUT
800
GPS SIGNAL
920
GEO-UNLOCK KEY
820
DATA ENCRYPTING KEY
524
GEO-LOCK KEY
GEO-RELOCK KEY
900
SHAPE PARM OUT
912
CIPHER KEY OUT
914

FIG. 9

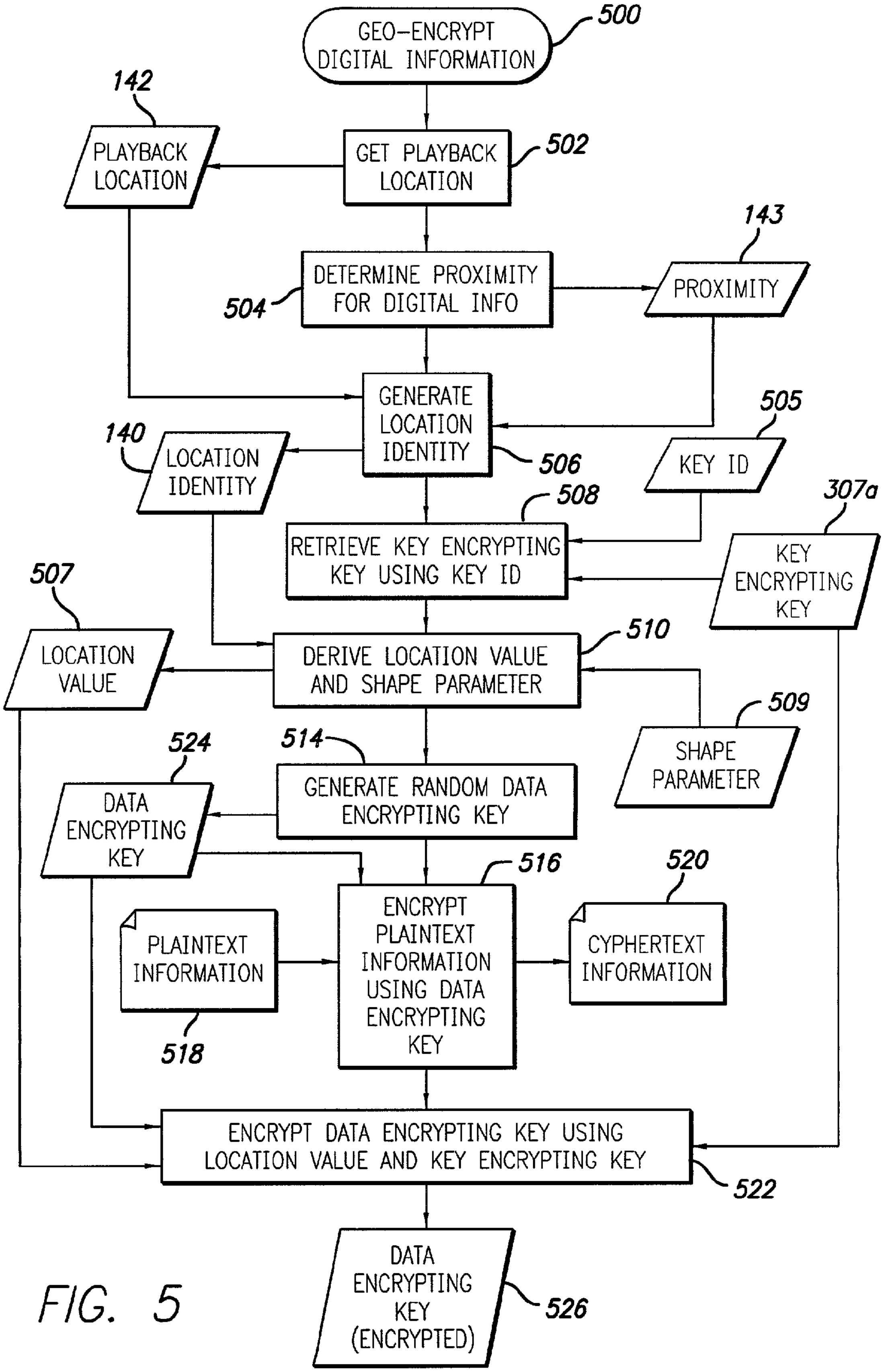

GEO-ENCRYPT DIGITAL INFORMATION
500
142
PLAYBACK LOCATION
GET PLAYBACK LOCATION
502
143
DETERMINE PROXIMITY FOR DIGITAL INFO
504
PROXIMITY
GENERATE LOCATION IDENTITY
505
140
LOCATION IDENTITY
506
KEY ID
508
307a
RETRIEVE KEY ENCRYPTING KEY USING KEY ID
KEY ENCRYPTING KEY
507
LOCATION VALUE
DERIVE LOCATION VALUE AND SHAPE PARAMETER
510
509
SHAPE PARAMETER
524
514
DATA ENCRYPTING KEY
GENERATE RANDOM DATA ENCRYPTING KEY
516
520
PLAINTEXT INFORMATION
ENCRYPT PLAINTEXT INFORMATION USING DATA ENCRYPTING KEY
CYPHERTEXT INFORMATION
518
ENCRYPT DATA ENCRYPTING KEY USING LOCATION VALUE AND KEY ENCRYPTING KEY
522
DATA ENCRYPTING KEY (ENCRYPTED)
526

FIG. 5

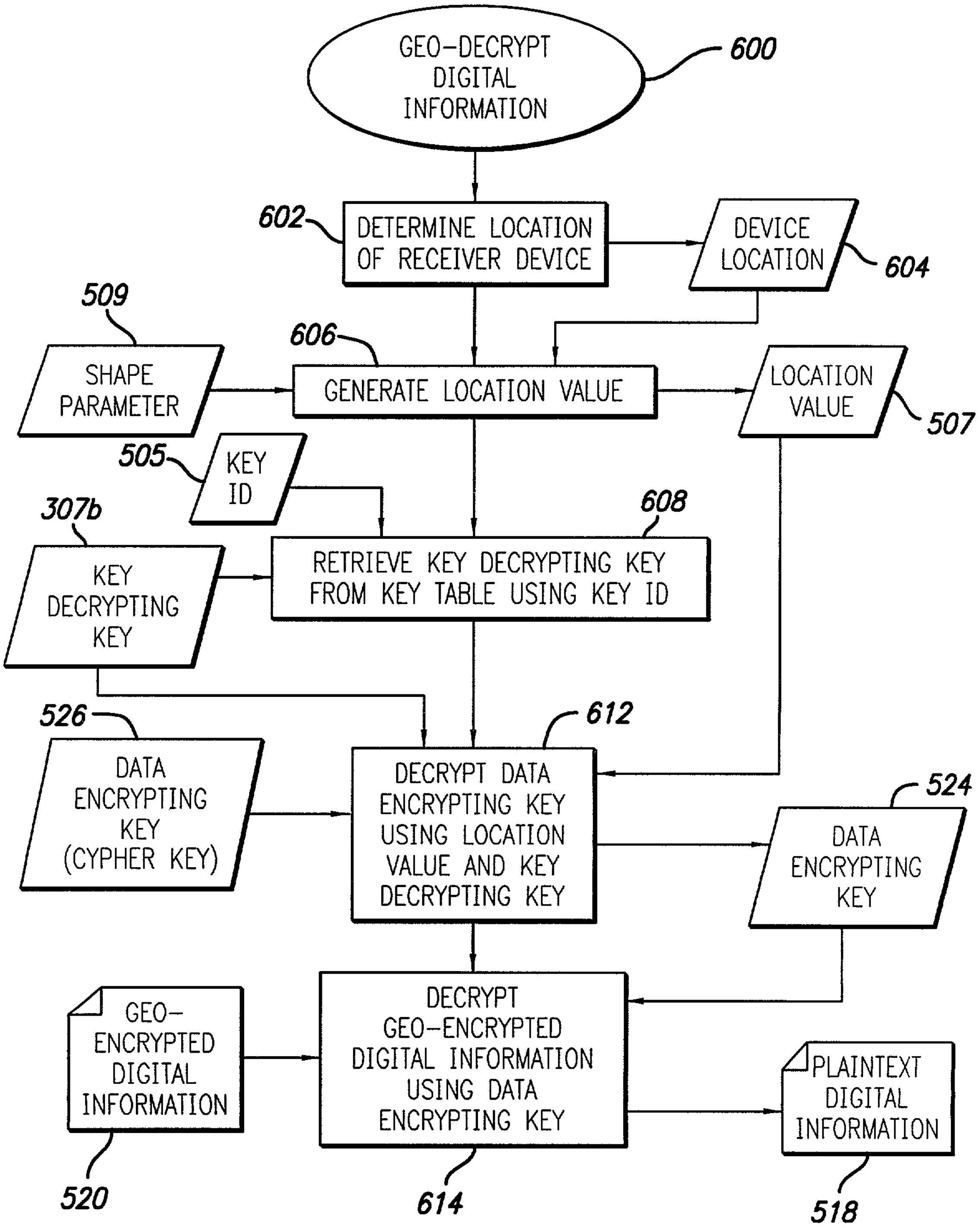
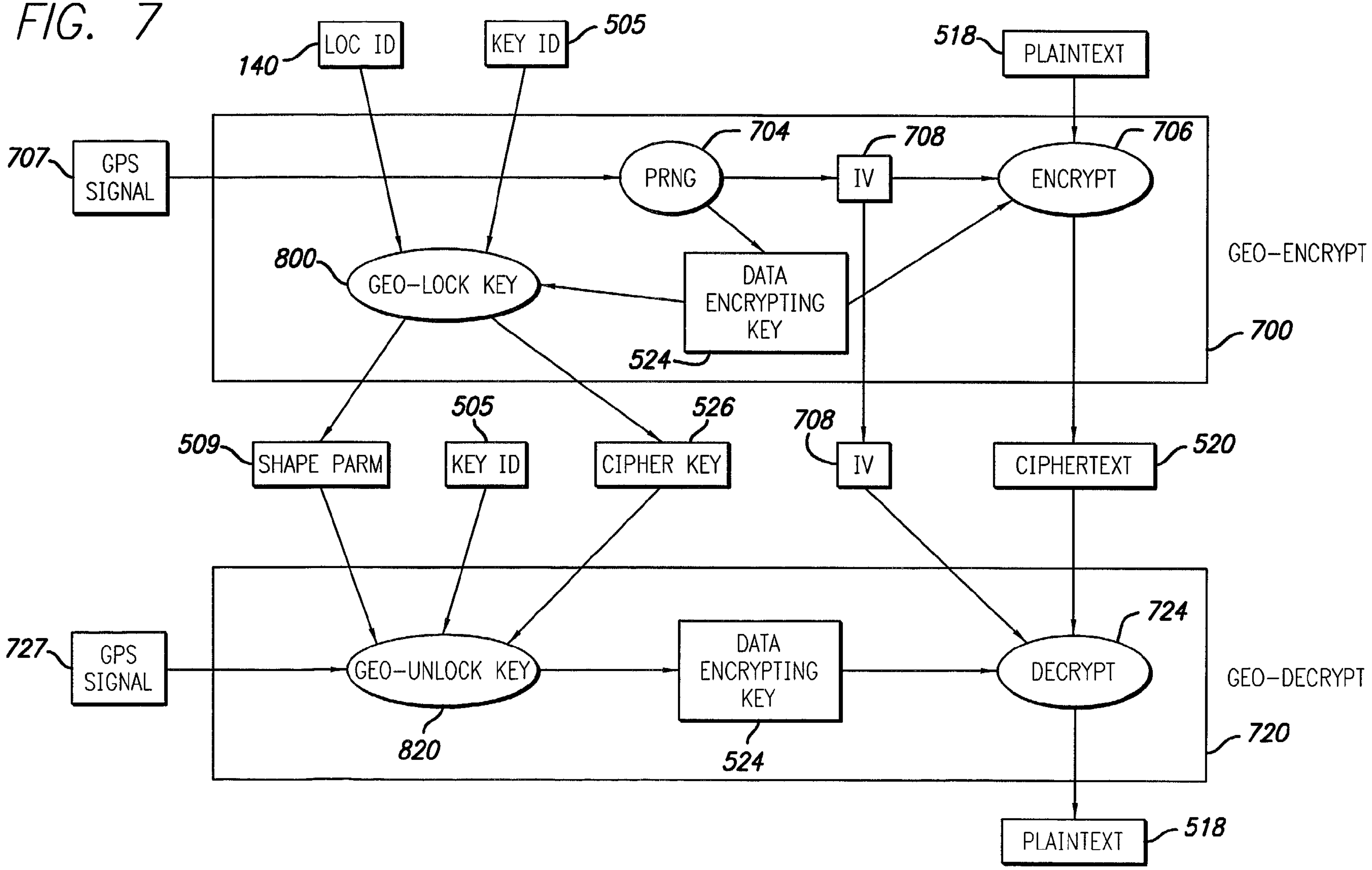

GEO-DECRYPT DIGITAL INFORMATION
600
602
DETERMINE LOCATION OF RECEIVER DEVICE
DEVICE LOCATION
604
509
SHAPE PARAMETER
606
GENERATE LOCATION VALUE
LOCATION VALUE
507
505
KEY ID
307b
608
KEY DECRYPTING KEY
RETRIEVE KEY DECRYPTING KEY FROM KEY TABLE USING KEY ID
526
612
DATA ENCRYPTING KEY (CYPHER KEY)
DECRYPT DATA ENCRYPTING KEY USING LOCATION VALUE AND KEY DECRYPTING KEY
524
DATA ENCRYPTING KEY
GEO-ENCRYPTED DIGITAL INFORMATION
DECRYPT GEO-ENCRYPTED DIGITAL INFORMATION USING DATA ENCRYPTING KEY
PLAINTEXT DIGITAL INFORMATION
520
614
518

FIG. 6

FIG. 7


LOC ID
140
KEY ID
505
PLAINTEXT
518
GPS SIGNAL
707
PRNG
704
IV
708
ENCRYPT
706
GEO-LOCK KEY
800
DATA ENCRYPTING KEY
524
GEO-ENCRYPT
700
SHAPE PARM
509
KEY ID
505
CIPHER KEY
526
IV
708
CIPHERTEXT
520
GPS SIGNAL
727
GEO-UNLOCK KEY
820
DATA ENCRYPTING KEY
524
DECRYPT
724
GEO-DECRYPT
720
PLAINTEXT
518

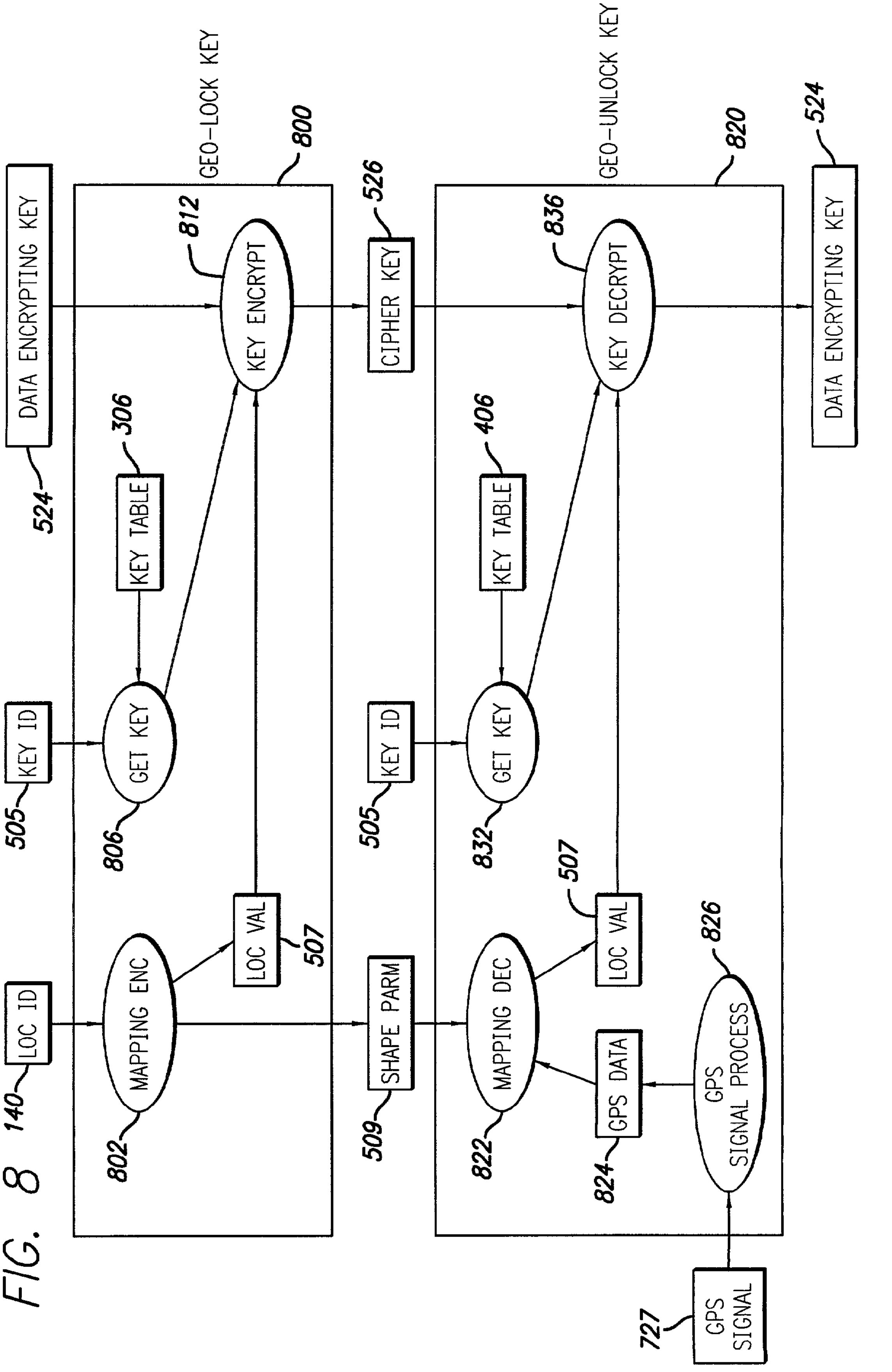


FIG. 8
GEO-LOCK KEY
800
DATA ENCRYPTING KEY
524
KEY ID
505
LOC ID
140
MAPPING ENC
802
GET KEY
806
KEY TABLE
306
KEY ENCRYPT
812
LOC VAL
507
CIPHER KEY
526
SHAPE PARM
509
GEO-UNLOCK KEY
820
KEY ID
505
MAPPING DEC
822
GET KEY
832
KEY TABLE
406
KEY DECRYPT
836
LOC VAL
507
GPS DATA
824
GPS SIGNAL PROCESS
826
GPS SIGNAL
727
DATA ENCRYPTING KEY
524

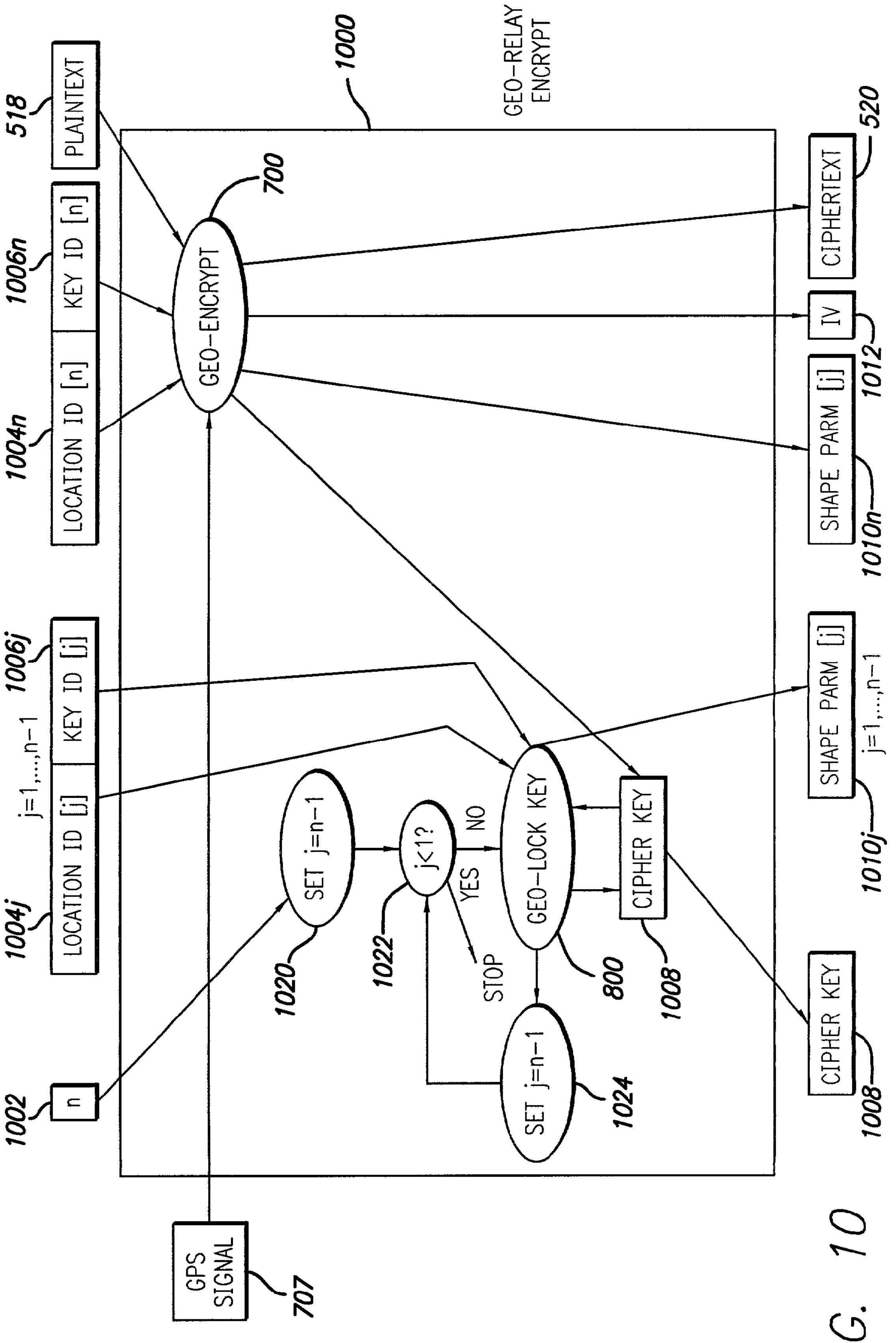

1000
GEO-RELAY ENCRYPT
518
PLAINTEXT
1006n
KEY ID [n]
1004n
LOCATION ID [n]
700
GEO-ENCRYPT
CIPHERTEXT
520
IV
1012
SHAPE PARM [j]
1010n
1006j
KEY ID [j]
j=1,...,n-1
1004j
LOCATION ID [j]
SHAPE PARM [j]
j=1,...,n-1
1010j
GEO-LOCK KEY
800
CIPHER KEY
1008
CIPHER KEY
1008
SET j=n-1
1020
j<1?
1022
NO
YES
STOP
SET j=n-1
1024
1002
n
GPS SIGNAL
707

FIG. 10

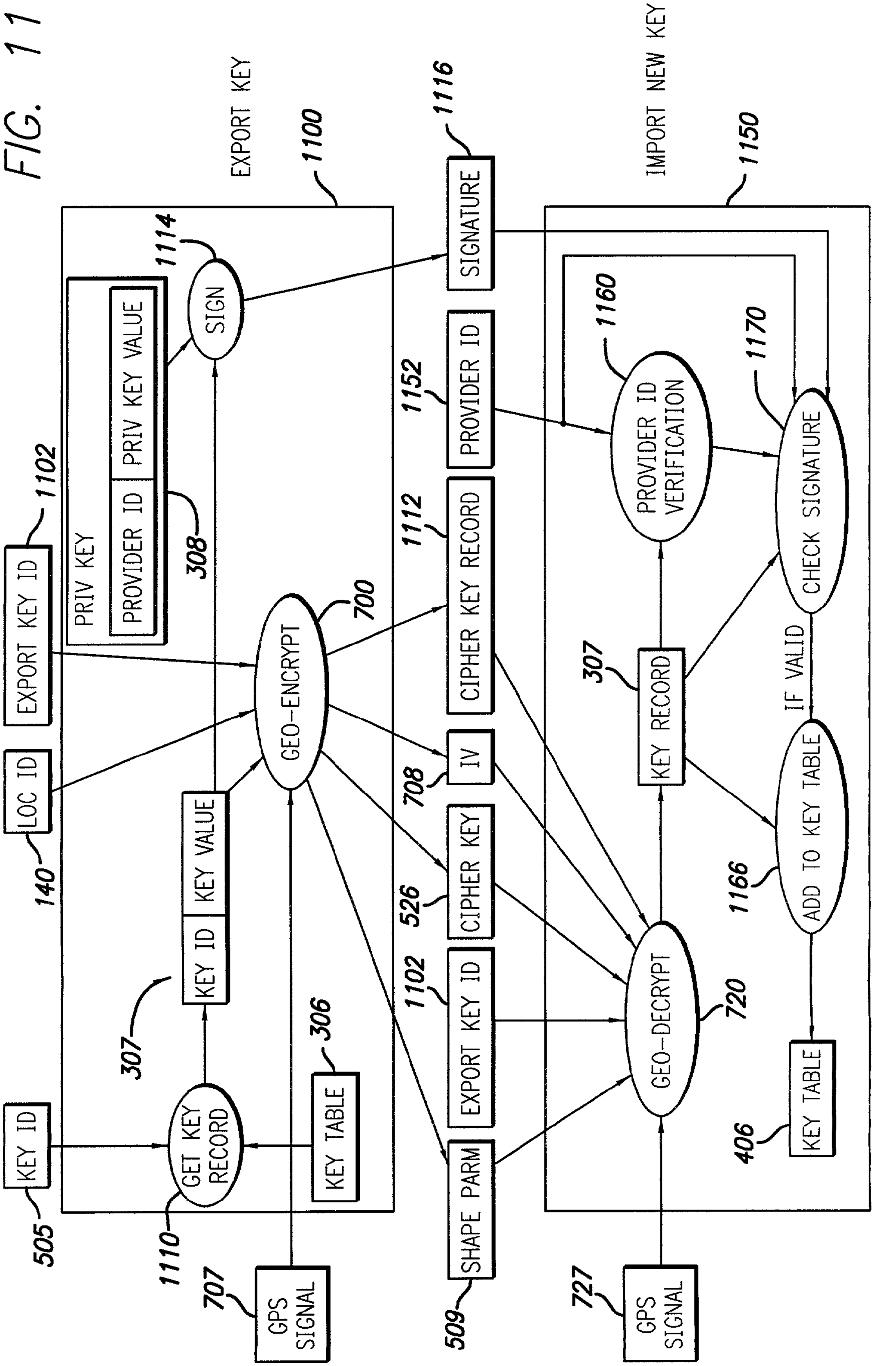

EXPORT KEY
1100
IMPORT NEW KEY
1150
KEY ID
505
GET KEY RECORD
1110
KEY TABLE
306
KEY ID
KEY VALUE
307
LOC ID
140
EXPORT KEY ID
1102
PRIV KEY
PROVIDER ID
PRIV KEY VALUE
308
SIGN
1114
GEO-ENCRYPT
700
GPS SIGNAL
707
SHAPE PARM
509
EXPORT KEY ID
1102
CIPHER KEY
526
IV
708
CIPHER KEY RECORD
1112
PROVIDER ID
1152
SIGNATURE
1116
GEO-DECRYPT
720
GPS SIGNAL
727
KEY RECORD
307
PROVIDER ID VERIFICATION
1160
CHECK SIGNATURE
1170
IF VALID
ADD TO KEY TABLE
1166
KEY TABLE
406

FIG. 11

SYSTEM AND METHOD FOR DELIVERING ENCRYPTED INFORMATION IN A COMMUNICATION NETWORK USING LOCATION IDENTITY AND KEY TABLES

RELATED APPLICATION DATA

This is a continuation-in-part of co-pending patent application Ser. No. 09/699,832, filed Oct. 30, 2000, for SYSTEM AND METHOD FOR USING LOCATION IDENTITY TO CONTROL ACCESS TO DIGITAL INFORMATION, and co-pending patent application Ser. No. 09/758,637, filed Jan. 10, 2001, for CRYPTOGRAPHIC SYSTEM AND METHOD FOR GEOLOCKING AND SECURING DIGITAL INFORMATION.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to controlling access to digital data through a communication network based on location. More particularly, the present invention relates to a method and apparatus for encrypting digital data in a communication network in such a manner that it can be decrypted only at a specified location and using a secret key.

2. Description of Related Art

Rapid advances in computer, telecommunications and networking technology have enabled new opportunities and applications that were impossible just a few years ago. These advances are exemplified by the rapid growth of network systems seeking to delivery "high-value" content securely to authorized recipients. Examples of such networks include those that handle confidential, sensitive, or classified information in the health care, financial, and national security fields. They also include networks that handle intellectual property or copyrighted data such as computer software, literary works, and entertainment products. Controlling the security of information in such systems, including confidentiality, authenticity, integrity, authorized use, transaction secrecy, site protection, etc., has proven to be a difficult problem that has reduced the benefit that businesses and consumers might otherwise enjoy from such systems.

One technology that is critical to protecting information on these networks is cryptography. Cryptography is the use of codes and ciphers to protect data from unintended disclosure or modification. It is primarily used to control access to communications transmitted over open networks, but may also be used to control access to stored data. In a transmission utilizing cryptography to protect digital data, the sender converts the original data, or "plaintext," into a coded equivalent called "ciphertext" using an encryption algorithm. The ciphertext is then decoded (or decrypted) by the receiver and thereby turned back into plaintext. The encryption algorithm uses a key, which in digital systems is a string of bits. In general, the larger the number of bits in the key, the longer it takes to break the code using so-called "brute force" methods.

Keys form the basis of all cryptographic systems. Two separate cryptographic key methods have been widely adopted by users of electronic networks: private-key cryptography and public-key cryptography. With private-key cryptography (also known as symmetric cryptography), the sender and receiver use a common secret key to encrypt and decrypt data. With public-key cryptography (also known as asymmetric cryptography), the sender and receiver use different but mathematically related keys to encrypt and decrypt the data. In particular, the sender encrypts the data using a public key that is unique to the receiver, while the receiver decrypts the data using the corresponding private key that is known only to the receiver. Because separate keys are used, public-key cryptography also can be used to provide digital signatures for authentication and non-repudiation. In this case, the sender signs the data using the sender's private key, while the receiver validates the data using the sender's public key.

Owing to their different mathematics, private-key cryptography is generally much more efficient than public-key cryptography. It runs faster and can provide comparable security using shorter keys. Consequently, most network systems use private-key cryptography to encrypt and decrypt most types of data. Public-key cryptography, if used at all, is presently used only to distribute the secret keys used with private-key cryptography and to digitally sign data.

The shared secret keys used with private-key cryptography can be distributed using either private-key or public-key methods. Private-key distribution methods are particularly well suited to broadcast and multicast applications where a central, shared server transmits data to one or more receivers simultaneously, such as subscription television, and to other applications that involve communications to or from a central server. Public-key distribution methods are particularly well suited to applications involving communications between two entities that do not trust each other and do not employ a shared server, such as electronic mail delivered across the Internet and connections between web browsers and web servers.

With both public-key and private-key cryptography, anyone knowing the secret key needed to decrypt the data can decrypt and access that data, assuming the method of encryption is known (which is generally assumed). It does not matter where the person is located or how the person acquired the data. For some applications, however, it would be desirable to control access to data based not only on a secret key, but also on location. For example, in the context of digital cinema, such a capability would enable a producer of digital movies to be assured that its products could only be decrypted in certain theaters whose locations would be known in advance. Or, a provider of entertainment products such as movies and subscription television would be assured that its products could only be decrypted within the premises of its customers or within a particular geographic region. This capability would guard against many threats, including the unauthorized distribution of copyright-protected works over the Internet or through other means. Even if the keys were compromised, recipients would not be at the proper location to enable decryption. The related patent applications referenced above disclose a method and system for encrypting digital data based on location.

It would also be desirable to have a capability to control access to data based on the distribution path of the data. For example, such a capability would enable a provider of protected works to be assured that its works were distributed through specific channels. Persons acquiring the product through other channels would then be unable to decrypt the data, even if they acquired the secret key. This capability could be used even when location is not a factor for authorizing decryption. Location-based encryption and path-dependent encryption would significantly enhance the security of data.

Another limitation of conventional encryption systems, particularly those that are based entirely on private-key cryptography, is that key management is vested with a single entity. Key management refers to the control over distribution of keys within a network. By restricting key management to a single entity, data providers that do not have key management authority are limited in their ability to control access to their digital data through the networks. Therefore, in addition to using location-based encryption and path-dependent encryption, it would be desirable to provide a method and system whereby multiple data providers can independently manage the secret keys they use to communicate with other providers and receivers.

SUMMARY OF THE INVENTION

In accordance with the present invention, access to digital data is controlled by encrypting the data in such a manner that, in a single digital data acquisition step, it can be decrypted only at a specified location and with a secret key. If the sender so elects, access to digital data also can be controlled by encrypting it in such manner that it must traverse a specific route from the sender to the recipient in order to enable decryption of the data.

Data encrypted in such a manner is said to be geo-encrypted. This geo-encryption process comprises a method in which plaintext data is first encrypted using a random data encryption key that is generated at the time of encryption. The data encrypting key is then encrypted (or locked) using a location value and a key encrypting key. The encrypted data encrypting key is then transmitted to the receiver along with the ciphertext data. The receiver both must be at the correct location and must have a copy of a corresponding key decrypting key in order to derive the location key and decrypt the data encrypting key. After the data encrypting key is decrypted (or unlocked), it is used to decrypt the ciphertext. If an attempt is made to decrypt the data encrypting key at an incorrect location or using an incorrect key decryption key, the decryption will fail. In addition, the encrypted data encrypting key or ciphertext optionally may be rendered unusable so that it becomes impossible to ever decrypt that particular ciphertext. The data encrypting key may also be encrypted in a manner that it can only be accessed at a certain time or during a specific time frame.

In accordance with an embodiment of the invention, the ciphertext data can be routed through one or more intermediary distributors before being transmitted to a final receiver. One method for doing this involves encrypting the data encrypting key with a location value and key encrypting key for the distributor. The distributor then decrypts the data encrypting key and re-encrypts it using a location value and key encrypting key for the receiver. The distributor does not have to decrypt the ciphertext, although nothing would prevent it from doing so. Another method for routing the ciphertext through a distributor involves encrypting the data encrypting key first with a location value and key encrypting key for the final receiver and then with a location value and key encrypting key for the distributor. The distributor removes its layer of encryption from the key before forwarding it to the receiver. If there are multiple distributors, the data encrypting key is successively encrypted with a location value and key encrypting key for each distributor on the path, but in reverse order. As the encrypted key is passed from one distributor to the next, each distributor removes its layer of encryption. With this method, none of the distributors can decrypt the data encrypting key because it remains encrypted with the location value and key encrypting key for the final receiver. Thus, the distributors cannot access the plaintext. This method also forces the ciphertext to follow a particular path to the receiver.

Another embodiment of the invention provides a method for distributing shared secret keys, specifically shared key encrypting/decrypting keys. These secret keys are transmitted from one place to another using the same techniques as for distributing any form of digital data. Specifically, a secret key that is to be distributed to a receiver is encrypted using a data encrypting key. The data encrypting key, in turn, is encrypted using a location value and an existing key encrypting associated with the receiver. The transmission is also digitally signed to ensure that only the owners of keys can create, change, and delete their keys. The sender can manage the secret keys required for decryption in a secure manner that is transparent to the recipient. As a consequence of its ability to manipulate the secret keys, the sender of encrypted data retains the ability to control access to its plaintext even after its initial transmission.

The aforementioned methods of the present invention employ a combination of private-key (i.e., symmetric) and public-key (i.e., asymmetric) cryptography. Plaintext data is encrypted and decrypted with private-key cryptography. The random data encryption key, however, can be encrypted and decrypted using either private-key cryptography or public-key cryptography. If private-key cryptography is used, the key encrypting key and key decrypting key are identical. The key encrypting/decrypting key is also kept secret. In contrast, if public-key cryptography is used, the key encrypting key is a separate public key, while the key decrypting key is a mathematically-related but distinct private key. Only the private, key decrypting key needs to be kept secret. Public-key cryptography is also used for authentication of the communications used to distribute the secret key encrypting/decrypting keys used with private-key cryptography. Public-key cryptography may also be used to authenticate other communications. It should be understood that private-key cryptography, public-key cryptography, or both could be used to distribute key decrypting keys in accordance with alternative embodiments of the invention.

In one embodiment of the invention, a communication network includes a producer device, a distributor device, a receiver device, and an administrator device. Each of these devices includes a key table that stores a plurality of key encrypting and key decrypting keys, and public and private signature keys. Some of these keys may be used with private-key cryptography, while others are used with public-key cryptography. The producer device encrypts the source digital data, such as a television episode or motion picture. The distributor device enables the secure transmission of the digital data initiated by the producer to either other distributors or to a designated receiver. The receiver device provides for receipt and end-user access to the plaintext of the digital data.

The administrator device has administrative control over some or all of the keys in the key tables. Providers, including producers, distributors and administrators, can add new keys to their own devices and to the devices of others, although they may be limited in the total number of keys that can be added to any particular device. Providers also can change and delete any key they own in any device. In addition, each user of the present invention may own one or more keys in the key table of their own device to handle their specific needs. Further, individual electronic devices within the communications network may incorporate any combination of producer, distributor, receiver and administrator functionality within a single unit so that a single node may embody whatever functionality is deemed appropriate.

In summary, the geo-encryption methods of the present invention extend the conventional methods of encryption to location-based and path-based encryption. If encrypted data is acquired at an unauthorized location or from an unauthorized channel through interception, transmission, or downloading, it cannot be decrypted because the location information pertaining to this unauthorized location would be inconsistent with the encrypted data. Further, if a device containing ciphertext is moved to a new, unauthorized location, it will not be possible to decrypt the ciphertext even if the device has the correct keys. It should be understood, however, that data could be securely moved between locations by authorized persons by re-encrypting or re-locking the random data encryption key for the new location. In order to compromise the geo-encryption, an adversary would have to know the encryption methods, location, and secret keys. Security ultimately depends on keeping the keys secret, since the methods and location may become known.

It should be appreciated that geo-encryption can be used even when location is not to be a factor in granting access. In that case, the encryption is made for a universal location that includes the entire world. This permits decryption anywhere in the world provided the receiver has the key decrypting key needed to decrypt the random data encrypting key. It also should be appreciated that geo-encryption can be used when time is not to be factor in granting access, thereby permitting decryption over an indefinite period of time.

A more complete understanding of the system and method for delivering encrypted information in a communication network using location identity and key tables will be afforded to those skilled in the art, as well as a realization of additional advantages and objects thereof, by a consideration of the following detailed description of the preferred embodiment. Reference will be made to the appended sheets of drawings, which will first be described briefly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic drawing illustrating access to digital information determined by location identity in accordance with an embodiment of the present invention;

FIG. **2** is a block diagram illustrating components of a location identity attribute;

FIG. **3** is a block diagram illustrating components of a location value of the location identity attribute;

FIG. **4**A is a block diagram illustrating an embodiment of a communications network in accordance with the invention;

FIG. **4**B is a block diagram illustrating an exemplary key table;

FIG. **5** is a flowchart illustrating a method for geo-encrypting digital information using a location identity attribute;

FIG. **6** is a flowchart illustrating a method for accessing geo-encrypted digital information using the location identity attribute;

FIG. **7** is a diagram illustrating the operation of exemplary Geo-Encrypt and Geo-Decrypt functions;

FIG. **8** is a diagram illustrating the operation of exemplary Geo-Lock Key and Geo-Unlock Key functions;

FIG. **9** is a diagram illustrating the operation of an exemplary Geo-Relock Key function;

FIG. **10** is a diagram illustrating the operation of an exemplary Geo-Relay Encrypt function; and

FIG. **11** is a diagram illustrating the operation of an exemplary Export Key and Import New Key functions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention satisfies the need to control the secure interchange of digital data so as to prevent unauthorized access to the data. More specifically, the present invention provides methods and apparatus for encrypting digital data in such a manner that it can be decrypted only at a specified location within a specified time frame and with a secret key. In the detailed description that follows, like element numerals are used to describe like elements illustrated in one or more of the figures. Various terms are used throughout the detailed description, including the following:

Administrator Device. A form of provider device (defined below) utilized by administrators of the keys stored in other devices.

Associating Location Identity. A method of marking digital data encryption keys with a location identity attribute.

Coordinate System. Location will be designated by latitude and longitude which is a coordinate system based on degrees that uniquely identifies any location on the Earth. Latitude is measured as an angle from the equator of the Earth (0 degrees) to the North Pole (90 degrees North) or to the South Pole (90 degrees South). Circles that run parallel to the plane of the equator form lines of latitude. All whole number latitude lines are equidistant from each other. A location's latitude is a measure of the angle between the plane of the equator and lines projected from the center of the Earth. Longitude lines are made by great circles that intersect with both the North and South Poles. Each longitude can be thought of as dividing the Earth in half. Longitudes are measured in half circles of 0 degrees to 180 degrees East and from 0 degrees to 180 degrees West from the Royal Greenwich Observatory in Greenwich, England. The 0 degree longitude line is also referred to as the prime meridian. A location's longitude is a measure of the angle between the plane made by its great circle and the prime meridian.

Distributor Device. A type of provider device (defined below) utilized by distributors of digital data.

Enforcing Location Identity. A method of providing or denying access to digital information through its associated location identity attribute.

Geocode. A unique coding of a location on earth usually associated with a coordinate system. Some geocodes identify a point location, such as when a place is identified by its latitude and longitude. Other geocodes may identify a region such as a zip code.

Geo-encrypt. An enforced association between a geographic area defined by a location identity attribute and digital data where access is granted to users within an area defined by the location identity attribute who also hold a secret key.

Geo-encrypted Data. Digital data containing encryption keys that have been associated with a location identity attribute, and that can only be accessed within an area defined by the location identity attribute using a secret key.

Location. A geographic place including, but not limited to, a precise point location, an area or region location, a point location included within a proximate area, or combinations of places on earth. Location can also include height (or altitude) to identify position above or below the surface of the earth, or time to identify position in a temporal dimension.

Location Identity. A precise coding of a location including, but not limited to, an attribute of information to precisely define the location at which the information is to be accessed. Location identity may be a coding of a point location, a region, a region with an associated point location, a corridor (i.e., center line with length on either side of the center line), or by any other precise identification of a location in space and time.

Location Variance. The minimum resolution at which a geocode of a location may fail to exactly distinguish it from adjacent locations.

Playback Location. The location portion of the location identity attribute at which access to digital information will be allowed.

Player Location. The location of a receiver device attempting to play back a geolocked file.

Producer Device. A form of provider device (defined below) utilized by producers of digital data.

Provider Device. Electronic devices, systems, networks, and the like with the minimum capacity to geo-encrypt and transmit digital data.

Proximity. A zone or area that includes the location.

Receiver Device. Electronic devices, systems, networks, and the like with the minimum capacity to receive and geo-decrypt digital data and keys, and to acquire location information. These electronic devices will often include a processing capability to execute program instructions and a memory capacity for short-term and long-term data storage, and may further include the ability to transmit information.

Universal Location. Any geographic place on earth.

The foregoing definitions are not intended to limit the scope of the present invention, but rather are intended to clarify terms that are used in describing the present invention. It should be appreciated that the defined terms may also have other meanings to persons having ordinary skill in the art. These and other terms are used in the detailed description below.

Referring now to FIG. **1**, a schematic illustration of the present invention depicts how access to digital data is determined by location identity. As defined above, location identity refers to an attribute of information that precisely determines the geographic area or region in which the information is accessible. Two geographic areas denoted by A and B are shown on a map **101** within the continental United States. Information **130** is represented in digital format, and has an associated location identity attribute **131** that precisely defines the geographic area A as the region in which the digital information can be accessed. If a receiver device **112** is located within the geographic region A, then the digital information **130** will be accessible by the receiver device. Conversely, if a receiver device **122** is located within the geographic region B (or anywhere else besides geographic region A), then the digital information **130** will not be accessible. Location identity thus represents an attribute of digital information that determines the precise geographic region within which the information can be accessed. Digital data having location-based encryption keys are termed "geo-encrypted" and systems that enforce location identity geolock the associated digital data to the geographic region defined by the location identity attribute.

FIG. **2** depicts a location identity attribute **140** as comprising two items of information: (a) a location value **142**, and (b) a proximity value **143**. The location value **142** corresponds to the unique geographic position of a particular place. Many different coordinate systems, such as latitude and longitude, have been developed that provide unique numerical identification of any location on earth. For the purposes of this invention, any coordinate system that uniquely identifies a place can be used for the location value **142** of the location identity attribute **140**. The proximity value **143** corresponds to the extent of a zone or area that encompasses the location. The location identity attribute **140** may comprise a point location or an exact location if the proximity value **143** is set to zero, null, empty, etc., or some other value indicating that the area referred to by the location identity attribute is a unique point location. It should be appreciated that the proximity value **143** is different from location variance. The proximity value **143** refers to a representation of an area or region, whereas location variance is the minimum resolution at which a geocode or a location may fail to exactly distinguish it from an adjacent location.

FIG. **3** depicts the location value **142** in greater detail. As noted above, there are numerous different coordinate systems in common use that provide a set of numbers that uniquely identify every location within the coordinate system. In the present invention, the location value **142** is defined in terms of a unique location designation or geocode as shown at **142***a*. Latitude **144** and longitude **145** using a conventional coordinate system may then further define the geocode. Other known systems, such as the Earth Centered, Earth Fixed Cartesian coordinate system, Universal Transverse Mercator (UTM), Military Grid Reference System (MGRS), World Geographic Reference System (GEOREF) etc., could also be advantageously utilized. In addition to latitude **144** and longitude **145**, the location value could further include an altitude **146** as shown at **142***b*, which corresponds to the height of the location above sea level. Alternatively, the location value could further include a time value **147** as shown at **142***c* that may be defined in terms of a date and/or time range. This allows the definition of location identity to consider both geographic and/or temporal access to information.

Any geographic region or area that contains the location value **142** of the location identity can serve as the proximity value **143** for the location identity attribute **140**. The proximity value **143** may comprise a rectangular region defined by two adjacent longitude lines (providing horizontal edges) and two adjacent latitude lines (providing vertical edges). Alternatively, the proximity value **143** may comprise a circular region represented by a single number defining the radius around the location. The circular region can be further defined as an elliptical area either centered at the location, or a circular or elliptical area that contains the location but not necessarily as the centroid. In another alternative, the proximity value **143** may comprise an irregular closed polygon, or a corridor. In yet another alternative, the proximity value **143** may correspond to a known geographic region, such as the country of Brazil. Other types of known geographic regions that can define the proximity value **143** can include postal zip codes, states, counties, incorporated cities, etc.

Referring now to FIG. **4**A, a block diagram illustrating an embodiment of a communications network employing methods and apparatus according to the invention. The communications network includes one or more producer devices **300**, one or more receiver devices **400**, and one or more administrator devices **310** that are coupled together via a network **200** (e.g., a wide area network such as the Internet). The producer devices **300** each denote a communication system utilized by a producer of digital data, such as a video production facility. The receiver devices **400** each denote a communications system utilized by an end user, such as a television set-top-box. The administrator devices **310** each denote a communication system utilized by an administrator of the communication network. As illustrated, producer devices **300**, administrator devices **310**, and receiver devices **400** are each respectively comprised of applications processors **302**, **312**, **402** and memory units **304**, **314**, **404**. It should be appreciated that there may be a plurality of producer devices **300**, administrator devices **310**, and receiver devices **400** within the communication network, and that the network would also be functional with just a single device in any one of the categories.

The communications network may be configured with the producer devices **300** in direct communication with the receiver devices **400**. Alternatively, one or more distributor devices **320** may also be connected to the aforementioned communications network interposed between the producer devices **300** and the receiver devices **400**. In this alternative configuration, information communicated from the producer devices **300** to the receiver devices **400** passes through the distributor devices **320**. As illustrated, distributor devices **320** are each comprised of an applications processor **322** and a memory unit **324**. In the description that follows, the term "provider device" is used to collectively refer to producer devices **300**, administrator devices **310**, and distributor devices **320** unless specified otherwise. Moreover, the manner in which the producer devices **300**, receiver devices **400**, administrative devices **310** and distributor devices **310** communicate is not critical to the invention, and any form of communication network having some or all of these components could be advantageously utilized. Further, communications from provider devices may be point-to-point to specific receiver devices or multicast to plural receiver devices simultaneously.

The producer devices **300**, administrator devices **310**, distributor devices **320** and receiver devices **400** also include respective GPS receivers **309**, **319**, **329**, **409** coupled to respective applications processors **302**, **312**, **322**, **402**. Specifically, it is anticipated that each of the devices has access to GPS signals and the respective GPS receivers can process those signals to produce location information, including latitude, longitude, altitude, and time, although all of these values may not be used. The receiver devices **400** (and in some cases the distributor devices **320**) use the location information processed by the GPS receivers **409** to determine location identity information (discussed below). The other devices use the GPS receivers to seed the generation of random numbers used in the encryption process (also described below). It should be appreciated that other methods of determining location identity information and/or generating random numbers could also be advantageously utilized as well known in the art.

The respective memory units **304**, **314**, **324**, and **404**, of the producer devices **300**, administrator devices **310**, distributor devices **320**, and receiver devices **400** may further comprise volatile and/or non-volatile memory components sufficient to store data, including information content, software instructions, and encryption keys. In a preferred embodiment of the invention, the memory units **304**, **314**, **324**, and **404** are further organized to include key tables **306**, **316**, **326**, and **406** that allow for the storage of a plurality of keys that are used with private-key and public-key cryptography. These keys are used by each device **300**, **310**, **320**, and **400** together with location information to encrypt and decrypt random data encryption keys and to sign and validate messages. The use and distribution of the keys within the key tables is an important aspect of the invention that will be described in greater detail below.

It should be appreciated that any of the producer devices **300**, administrator devices **310**, distributor devices **320**, and/or receiver devices **400** can be implemented in hardware or software. The preferred embodiment is a tamperproof hardware device that would protect both the secrecy of keys and the integrity of the functions performed by the devices; however, the functions themselves do not have to be kept secret. The devices further may be included in larger systems or devices that handle the communications and perform other application-related functions and auditing functions. Auditing functions might log the use of the device and, possibly, transmit that information to a designated auditing entity.

For example, in one embodiment, a receiver device **400** might be included in a set-top-box (STB) used by video service providers to receive broadcast entertainment content (e.g., television shows, movies, and other video programming). Whenever a program is decrypted, an audit record could be returned to the provider of the program. The STB would have the capability to show a decrypted program on the monitor, but not to save or transmit the plaintext. In another embodiment, a receiver device **400** might be built into the equipment used at a movie theater. The equipment might have the capability to show a decrypted program and store the content for a limited period of time, but not to transmit the plaintext. A provider device **300**, **310**, **320** might be built into a computer system or such other equipment that is used to create, process, and transmit data.

In accordance with an embodiment of the present invention, the provider devices **300**, **310**, **320** need to know the location of the receiver devices **400** (or other ones of the provider devices). The provider devices **300**, **310**, **320** may query the receiver devices **400** upon connection to the communication network, which then report back the location information derived from GPS signals (or other method) to the provider devices. Alternatively, in the foregoing example, the video service providers may already know the location of the set-top-boxes since they correspond to the physical address of customers of the video service providers. Each set-top-box may further include a unique serial number that the provider devices **300**, **310**, **320** can use to identify the receiver devices **400**.

In a preferred embodiment, the key tables **306**, **316**, **326**, **406** contain the keys that each respective device uses to encrypt or decrypt random data encryption keys and to sign or validate messages. As shown in FIG. **4**B, an exemplary key table **306** contains a plurality of key records $\mathbf{307}_1$–$\mathbf{307}_N$. The key records **307** (also referred to herein simply as "keys") each include a unique key identification (ID) that further comprises an Owner Identification (ID) code and a key name. The key records **307** further include the associated key value (illustrated as KEY **1** through KEY N). Every key in the table has an owner that is determined by the corresponding Owner ID. The key name simply gives the name of the key while the key value gives the actual string of bits comprising the key. It should be understood that the key records **307** might also contain other information, including the type of key and encryption method used with that key. For example, the key record **307** could specify whether the key is to be used with private-key cryptography or public-key cryptography, and, if the latter, whether the key is a public-key encrypting key, private-key decrypting key, private signature key, or public signature validation key. The key records **307** might also contain an expiration date. The key records **307** for the public and private keys used with public-key cryptography might include digital certificates for the keys. Some of this additional information may be part of the key identification. The other key tables **316**, **326**, **406** will have generally similar construction.

For example, the keys used by a television producer (e.g., AOL-Time Warner, Inc.) to protect the data it produces for television viewing could have key IDs with an owner ID uniquely identifying this particular television producer as well as a plurality of key names, each of which uniquely identifies a particular channel or network owned by the television producer (e.g., HBO®, TNT®, TBS®, CARTOON NETWORK®, CNN®, CINEMAX®, etc.). Similarly, another television producer (e.g., The Walt Disney Co.) could have key IDs with an owner ID unique to this particular television producer along with key names corresponding to particular channels or networks owned by this other television producer (e.g., Disney Channel®, ESPN®, ABC®, etc.).

In an embodiment of the invention, administrators will own at least one key in the key table of every device. It should be appreciated that these keys could be unique to individual devices or common among multiple devices. One of these keys might be common to all devices, allowing any provider device **300**, **310**, **320** to transmit encrypted data to any receiver device **400**. In addition, a provider of geo-encrypted data may own one or more keys in the key tables of devices that are allowed to receive and decrypt data from that provider. In another embodiment, each device **300**, **310**, **320**, **400** might own its own public-private key pair. The public key of the exemplary device could be given to any provider device, allowing the provider device to transmit encrypted data to the exemplary device without the need for a common key. It should be appreciated that many possible arrangements of keys are possible.

The keys in the key table are used to protect the transmission of data encryption keys. Specifically, they are used with location information to encrypt and decrypt the data encryption key and to sign and validate data. It should be appreciated that secret keys in the key tables **306**, **316**, **326**, **406** would remain within the associated device while in use and would never leave the device in unencrypted form. The key table could be organized in any way, for example, as a sequential or linked list, binary search tree, or hash table. It also could be implemented as a database or other type of data repository. Secret keys cannot be exported from the device in the clear, but they can be exported in encrypted form. Operations for adding, changing, and deleting keys to/from a key table will be described later. It should be appreciated that in any given device keys could be distributed over multiple key tables or not even stored in a table per se. Accordingly, the key tables described herein are intended to denote the entire collection of keys within a device in any manner in which they are stored, maintained and/or organized.

In a preferred embodiment, digital data is geo-encrypted using a set of functions embedded within a provider device **300**, **310**, **320**. This geo-encrypted data is then transmitted to one or more receiver devices **400** where it is decrypted using a set of functions embedded within the receiver device **400**. The transmission can be point-to-point, broadcast or multicast. The geo-encrypted data has a location identity attribute **140** associated therewith so that subsequent access of the digital information is limited to the geographic area specified by the location identity attribute **140**. FIG. **5** illustrates a general method for associating digital information with the location identity attribute **140** that precisely defines the region in which access or playback of the digital information will be allowed. In the present invention, this method would be performed either via a producer device **300**, an administrator device **310** or a distributor device **320**.

More particularly, the method starts at step **500** with a command to geo-encrypt digital information using a location identity attribute. A first part of the method provides for the generation of the location identity attribute. At step **502**, a playback location value **142** for the digital information is retrieved and stored for later use. The playback location value **142** is not the geographical location at which the method is performed by the provider device **300**, **310**, **320**, but rather corresponds to the geographical location for a receiver device **400** at which access to the digital information will be allowed. At step **504**, a proximity value **143** of the location identity attribute of the receiver device **400** is retrieved and stored for later use. Various methods for generating the location and proximity values **142**, **143** will be described in greater detail below. In addition to such methods, the location and proximity values **142**, **143** may also be pre-stored and retrieved from memory, or the end user may be queried to provide the information. At step **506**, the playback location and proximity values **142**, **143** are used to generate the location identity attribute **140**.

A second part of the method provides for the generation of encryption keys and the encryption of the plaintext digital information. At step **508**, a key ID **505** is used to select and retrieve a key encrypting key **307***a* from the key table of the corresponding provider device **300**, **310**, **320**. The location identity **140** is then used at step **510** to derive a location value **507** and a shape parameter **509**. The shape parameter **509** defines a shape of an area of interest without identifying the specific location corresponding to the area of interest. The shape parameter **509** is a locationless translation of the proximity portion of the location identity attribute **140**. Locationless refers to the characteristic of the shape parameter **509** as defining the shape of a proximate area without reference to any actual location. As will be further described below, the receiver device **400** uses the shape parameter **509** to fully determine the location value needed for recovering the location key.

Then, at step **514**, the process generates a random data encrypting key **524**. This data encrypting key **524** is used to encrypt the plaintext digital information **518** at step **516** to produce geo-encrypted digital information **520**. The data encrypting key **524** is then encrypted at step **522** using the location value **507** and the key encrypting key **307***a*. The geo-encrypted digital information **520**, the encrypted data encrypting key **526** (also referred to below as a cipher key), the shape parameter **509**, and the key ID **505** are then communicated to the receiver device **400**. Attempts to decrypt the geo-encrypted information **520** by a receiver device **400** will be denied unless the location of the receiver device **400** matches the location specified by the location identity attribute **140** and the receiver device **400** has the correct key decrypting key identified by the key ID **505**.

FIG. **6** shows a general method for enforcing access to geo-encrypted digital information by location. Software or embedded firmware instructions operating in association with the applications processor **402** of the receiver device **400** would cause the method to be performed. Particularly, the method starts at step **600** with a command to decrypt the geo-encrypted digital information **520**. A first part of the method provides for the generation of the location value **507**. At step **602**, the method determines the location of the receiver device. It should be appreciated that numerous ways to determine the receiver device location are possible and are described in the aforementioned co-pending patent applications commonly owned by the applicant. In a preferred embodiment, the GPS receiver **409** within or coupled to the receiver device **400** provides this location information **604**. The device location information **604** is then used in conjunction with the shape parameter **509** received from the provider of the geo-encrypted digital information to generate the location value **507** at step **606**. As will be appreciated, the location value **507** generated by the receiver device must match the location value **507** used by the provider device to geo-encrypt the digital information, otherwise the receiver device **400** will be unable to geo-decrypt the encrypted digital information **520**.

In a second part of the method, the location value **507** is used with a key decrypting key **307***b* to geo-decrypt the encrypted digital information. The key decrypting key **307***b* is retrieved from the key table of the receiver device at step **608** in accordance with the key ID **505** received from the provider device. It should be appreciated that the key decrypting key **307***b* retrieved at step **608** must correspond to the key encrypting key **307***a* used in geo-encrypting the digital information; otherwise, the geo-decryption will fail. At step **612**, the selected key decrypting key **307***b* and the generated location value **507** are used to decrypt the data encrypting key **526**. If the location of the receiver device is consistent with the location value **507** used by the provider device, the decryption will recover the original data encrypting key **524**. Lastly, the data encrypting key **524** is used to decrypt the geo-encrypted digital information **520** to recover the plaintext digital information **518** at step **614**.

Table 1 provided below lists an exemplary set of functions used in an embodiment of the present invention. It should be appreciated that these functions can be incorporated into one or more of the aforementioned producer devices **300**, administrator devices **310**, distributor devices **320**, and receiver devices **400**. For each such function, Table 1 lists the values used as inputs (i.e., parameters) to the function and the corresponding values produced as outputs (i.e., results) of the function. It should be appreciated that all functions using cryptography in Table 1 use location information in some way. It should be further appreciated that these functions do not necessarily have to be implemented as separate procedures or distinct program units of any type, and could instead be combined or split into multiple units. It should also be noted that the inputs and outputs shown in Table 1 are not necessarily external to a device and may instead be passed from one function to another within a single device. All of the functions described herein could further include error checking and handling, and it is anticipated that conventional methods for performing these functions be utilized. A brief description of each function listed in Table 1 is provided with greater detail within the text below.

TABLE 1

Basic Functions

Function	Inputs/Parameters	Outputs/Results	Description
Geo-Encrypt	Location ID, Key ID, Plaintext	Shape Parm, Cipher Key, IV, Ciphertext	Encrypt data and lock the data encryption key using a location-derived secret key
Geo-Decrypt	Shape Parm, Key ID, Cipher Key, IV, Ciphertext	Plaintext	Decrypt data after unlocking the key
Geo-Lock Key	Location ID, Key ID, Data Encrypting Key	Shape Parm, Cipher Key	Lock data encryption key with location-derived secret key
Geo-Unlock Key	Shape Parm, Key ID, Cipher Key	Data Encrypting Key	Unlock data encryption key with location-derived secret key
Geo-Relock Key	Shape Parm In, Key ID In, Cipher Key In, Location ID Out, Key ID Out	Shape Parm Out, Cipher Key Out	Unlock data encryption key with one location-derived secret key and lock it with another
Geo-Relay Encrypt	n, Location ID [j] for j from 1 to n, Key ID [j] for j from 1 to n, Plaintext	Shape Parm [j] for j to 1 to n, Cipher Key, IV, Ciphertext	Encrypt data and lock the data encryption key with multiple locks that must be unlocked by successive relay stations before the data can be decrypted
Create Key Replace Key Delete Key	Key ID		Create and add secret key to Key Table, replace key with new value, or delete key
Export Key	Key ID, Location ID, Export Key ID	Shape Parm, Cipher Key, IV, Cipher Key Record, Signature	Geo-encrypt a key record in the Key Table so that it can be securely exported to another Key Table
Import New Key Import Replacement Key Import Deletion Key	Shape Parm, Export Key ID, Cipher Key, IV, Cipher Key Record, Provider ID, Signature		Add, change, or delete a key record in the Key Table by importing a geo-encrypted key record and performing the operation only if signed by the owner or by an administrator

As described above, the provider devices **300**, **310**, **320** include a key table **306**, **316**, **326** and a private key **308**, **318**, **328**, respectively, and may receive a GPS signal as an input used to derive location information for decryption and to generate random values. The provider devices are adapted to execute a first set of functions, including Geo-Encrypt, Geo-Lock Key, Geo-Unlock Key, Geo-Relay Encrypt, and Geo-Relock Key. The provider devices may also be adapted to execute a second set of functions, including Create Key, Replace Key, Delete Key, Export Key, Import New Key, Import Replacement Key, and Import Deletion Key. The first set of functions are used to manage the encryption and decryption of information using the keys contained in the key table, and the second set of functions are used to manage the various key values in the key tables. In a preferred embodiment of the invention, the provider devices **300**, **310**, **320** include all of the functions identified in Table 1, the operation of which will be discussed in greater detail below.

The receiver devices **400** also include a key table **406** and receive a GPS signal as input. In a preferred embodiment, the receiver devices **400** contain only functions needed to decrypt geo-encrypted data and receive keys. In particular, receiver devices **400** are adapted to execute the Geo-Decrypt and Geo-Unlock functions. The receiver devices may also be adapted to execute the Import New Key, Import Replacement Key, and Import Deletion Key functions. These functions enable users to receive and decrypt geo-encrypted data and keys, but not to geo-encrypt data or keys. The operation of these functions will also be discussed in greater detail below.

It should be appreciated that other combinations of functions are possible. For example, a distributor device **320** could be given somewhat different functionality from that of a producer device **300**. Or, a single provider device **300**, **310**, **320** might be used by all entities that produce, distribute, and/or receive geo-encrypted data. If receiver devices **400** are to have the capability to geo-encrypt their own files and share them with other users, then they would likely need most, if not all, of the functionality of a provider device **300**, **310**, **320**, including the capability to own their own keys and share keys with other devices. It should also be appreciated that the devices may include functions that are not described herein. They may have additional functions to manage the key tables, for example, to limit the number of keys that an owner can include in a key table or to allow an owner to determine which of its keys are included in a key table. The devices may further include functions providing additional capabilities associated with digital rights management.

The operation of the Geo-Encrypt and Geo-Decrypt functions **700**, **720** are illustrated in FIG. **7** with reference to Table 1. The Geo-Encrypt function **700** has three inputs, including: (1) Location Identity (Loc ID) **140**; (2) Key ID **505**; and (3) Plaintext **518**. The Geo-Encrypt function **700** encrypts the Plaintext **518** according to the location identified by Location ID **140** in such a manner that the data can be decrypted only by a device that both is at that location and has the secret key identified by the Key ID **505**. As a result, the Geo-Encrypt function **700** yields four outputs, including: (1) Shape Parameter (Shape Parm) **509**; (2) Cipher Key **526**; (3) Initialization Value (IV) **708**; and (4) Ciphertext **520**. The Geo-Encrypt function **700** includes as sub-functions pseudo-random number generator (PRNG) **704** and Encrypt **706**, and also accesses the Geo-Lock Key function **800** (described below with respect to FIG. **8**).

More particularly, the Geo-Encrypt function **700** generates a Data Encrypting Key **524** using the PRNG sub-function **704**. In a preferred embodiment, the PRNG sub-function **704** is provided with raw GPS signal data **707** in addition to other non-deterministic information (e.g., determined by the state of the device). Assuming an initialization value (IV) is to be used, the PRNG sub-function **704** also generates a random IV **708**. The Encrypt sub-function **706** then encrypts the Plaintext **518** using both the Data Encrypting Key **524** and the IV **708** to produce a Ciphertext output **520**. The Data Encrypting Key **524** is locked (i.e., encrypted) using the Geo-Lock Key function **800**, using a location value derived from the location identified by the Location ID **140** and from the key encrypting key identified by the Key ID **505**. The Geo-Lock Key function **800** provides as outputs Shape Parameter **509** and Cipher Key **526**.

In a preferred embodiment, the Encrypt sub-function **706** comprises a strong encryption method, such as the Advanced Encryption Standard (AES), which has a block size of 128 bits and uses keys of size 128, 192, and 256 bits. It should be appreciated that any other method of encryption can also be used. The particular mode of encryption would depend on the algorithm, length of the Plaintext **518**, and the application. Normally, when the Plaintext **518** is longer than a block or two, a mode such as output feedback, cipher feedback, or cipher block chaining is used. In that case, the encryption process uses the initialization vector (IV) **708** to initialize the encryption process. In a preferred embodiment, the IV **708** is transmitted to the receiver device **400** in order to initialize the decryption process. It should be noted, however, that the IV **708** does not have to be encrypted.

The Geo-Decrypt function **720** has five inputs, including: (1) Shape Parm **509**; (2) Key ID **505**; (3) Cipher Key **526**; (4) IV **708**; and (5) Ciphertext **520**. The Geo-Decrypt function **720** decrypts Ciphertext **520** using Data Encrypting Key **524** and IV **708**, and includes sub-function Decrypt **724** and accesses the Geo-Unlock Key function **820** (described below with respect to FIG. **8**). Data Encrypting Key **524** is determined by unlocking the Cipher Key using the Geo-Unlock Key function **820**. The Geo-Unlock Key function **820** decrypts the Cipher Key **526** using the key decrypting key identified by Key ID and a location value determined from the Shape Parm **509** and a GPS signal **727** in order to yield the Data Encrypting Key **524**. The Decrypt sub-function **724** decrypts the Ciphertext **520** using the Data Encrypting Key **524** and IV **708** in order to reconstruct the Plaintext **518**. It should be appreciated that the Decrypt sub-function **724** would be the inverse of the Encrypt sub-function **706** used by the Geo-Encrypt function **700** described above.

In an embodiment of the invention, the Geo-Decrypt function **720** goes further and tests whether the recovered Plaintext **518** is authentic. For example, this procedure may be done using a message authentication code (MAC) that would be computed by the Geo-Encrypt function **700** as a function of the Plaintext **518** and included with the data. It should be understood that any known method of computing a MAC could be used. After decrypting the Ciphertext **520**, the Geo-Decrypt function **720** would then compute a MAC for the recovered Plaintext **518** If the MAC matches that computed by the Geo-Encrypt function **700** and included with the data, then it can be assumed that the data was correctly decrypted. This implies that the Geo-Decrypt function **720** was performed at the correct location and that it used the correct key decrypting key. If the MAC does not match, then the Geo-Decrypt function **720** could output an indicator to this effect. Alternatively, the Geo-Decrypt function **720** could take action that would henceforth render the data undecipherable. For example, the Geo-Decrypt function **720** could nullify the Cipher Key **526** by replacing it with all zeros. With this additional capability, the Geo-Decrypt function **720** can ensure that, if an attempt is made to decrypt data at an incorrect location or using an incorrect key decrypting key, any further attempts to decrypt the data will fail.

FIG. **8** illustrates the operation of the Geo-Lock Key and Geo-Unlock Key functions **800**, **820** with reference to Table 1. The Geo-Lock Key function **800** is used to encrypt the

Data Encrypting Key **524** so that it can be securely distributed to a receiver device **400**. The Geo-Lock Key function **800** has three inputs, including: (1) Location ID (Loc ID) **140**; (2) Key ID **505**; and (3) Data Encrypting Key **524**. The Geo-Lock Key function **800** further includes a Mapping Encrypt (Mapping Enc) sub-function **802**, a Get Key sub-function **806**, and a Key Encrypt sub-function **812**. The Geo-Lock Key function generates two outputs, including: (1) Cipher Key **526**; and (2) Shape Parm **509**.

The Mapping Encrypt sub-function **802** converts the Location ID **140** into a Location Value (Loc Val) **507** and the Shape Parm **509**. In a preferred embodiment, the Mapping Encrypt sub-function **802** comprises a mapping function such as that described in co-pending patent application Ser. No. 09/758,637 commonly owned by the applicant, incorporated by reference herein. Particularly, the mapping function is used to map different coordinates within a proximate area into the same values. The mapping function is as follows:

$$f(x)=\Delta^*\mathrm{int}(x/\Delta)$$

where int is a function that returns the integer part of its argument in parentheses. Using x as the latitude of the geocode location and Δ as the length of the side between the bounding latitudes; or x as the longitude of the geocode location and Δ as the length of the side between the bounding longitudes, a grid may be constructed over the entire latitude/longitude coordinate system. Every geocode within a grid cell will be transformed into the same value when the above function is applied to its latitude and longitude. Since the "great rectangle" boundaries may not fall directly on boundaries that are exact multiples of the length of the bounding sides, a locationless offset measure is calculated using the lower bounding side and is used to linearly shift the grid. It should be appreciated that other methods for computing Location Value **507** and Shape Parm **509** may also be employed within the scope and spirit of the present invention.

The Get Key sub-function **806** uses the Key ID **505** to retrieve the appropriate key encrypting key **307***a* from a key table **306**. Then, the Key Encrypt sub-function **812** encrypts the Data Encrypting Key **524** using the Location Value **507** and the key encrypting key **307***a*. In a preferred embodiment, the Key Encrypt sub-function **812** first takes the exclusive-OR of the Data Encrypting Key **524** and the Location Value **507**, and then encrypts the result using the key encrypting key **307***a*. The encryption would be implemented with a strong encryption method such as the AES if private-key encryption is being used or RSA if public-key encryption is being used, although it should be appreciated that other encryption methods could be used. In an alternative embodiment, the Key Encrypt sub-function **812** first encrypts the Location Value **507** with the key encrypting key **307***a* and then uses the result of that to encrypt the Data Encrypting Key **524**. With this embodiment, the Key Encrypt sub-function **812** must use private-key cryptography.

It should be appreciated that the Geo-Lock Key function **800** can be used to encrypt any key, not just the Data Encrypting Key **524** used to encrypt the Plaintext data. For example, the Geo-Lock Key function **800** can be used to place an additional lock on an already encrypted key. Thus, the Data Encrypting Key **524** used by the Geo-Lock Key function **800** (and Geo-Unlock Key function **820**) should be understood to refer to any key, whether already encrypted or not.

The Geo-Unlock Key function **820** is used to recover the Data Encrypting Key **524** from the Cipher Key **526**. The Geo-Unlock Key function **820** has three inputs, including: (1) Shape Parm **509**; (2) Key ID **505**; and (3) Cipher Key **526**. The Geo-Unlock Key function **820** further includes a Mapping Decrypt (Mapping Dec) sub-function **822**, a GPS Signal Processing sub-function **826**, a Get Key sub-function **832**, and a Key Decrypt sub-function **836**. The Geo-Unlock Key function **820** generates a single output, i.e., Data Encrypting Key **524**.

The GPS Signal Processing sub-function **826** receives a GPS signal **727** and processes the signal to determine the location of the receiver device **400** in terms of GPS coordinate data **824**. The Mapping Decrypt sub-function **822** uses the GPS data **824** along with the Shape Parm **509** to determine the Location Value **507**. As described above, the Mapping Decrypt sub-function **822** employs a mapping function such as that described in co-pending patent application Ser. No. 09/758,637. It should be appreciated that different methods for computing Location Value **507** could also be used. The Get Key sub-function **832** operates substantially the same as the Get Key sub-function **806** described above. Particularly, the Get Key sub-function **832** uses the Key ID **505** to retrieve the appropriate key decrypting key **307***b* from a key table **406** of the receiver device **400**. The Key Decrypt sub-function **836** decrypts the Cipher Key **526** using the Location Value **507** and the key decrypting key **307***b* to recover the Data Encrypting Key **524**. It should be noted that the Key Decrypt sub-function **836** is substantially the inverse of the Key Encrypt sub-function **812** described above. In a preferred embodiment, the Key Decrypt sub-function **836** first decrypts the Cipher Key **526** using the key decrypting key **307***b*. This is performed using either private-key or public-key cryptography, depending on which was used by the Key Encrypt sub-function **812**. The Key Decrypt sub-function **836** then takes the exclusive-OR of the result with the Location Value **507** to recover the Data Encrypting Key **524**. In an alternative embodiment, the Key Decrypt sub-function **836** first encrypts the Location Value **507** with the key decrypting key **307***b*, and then uses the result to decrypt the Cipher Key **526** and recover the Data Encrypting Key **524**. In this case, private-key cryptography is used for all steps, so the key decrypting key **307***b* is the same as the key encrypting key **307***a*. If the receiver device **400** does not have access to GPS signals either because it is not GPS-enabled or for some other reason, it should be appreciated that Location Value **507** may be set to a universal location. As a result, this will allow data intended for all locations to be decrypted from any location, but not other data.

When encrypted data (i.e., Ciphertext **520**) is transmitted to a receiver device **400**, it is transmitted along with a Cipher Key **526**. The Cipher Key **526** contains the Data Encrypting Key **524** enciphered in a location-dependent manner. In a preferred embodiment, re-encryption would then involve deciphering (i.e., unlocking) the Data Encrypting Key **524** and re-enciphering (i.e., locking it with a different location value). It should be appreciated that the Ciphertext **520** itself is not decrypted and re-encrypted. Relay encryption is similar, except that the Cipher Key **526** is not initially unlocked. Instead, one or more additional locks are placed on top of the Cipher Key **526**. Thus, the original key may be nested under several layers of encryption, all of which have to be removed in order to restore the original key. The specific functions used to perform these tasks are described in greater detail below.

FIG. **9** illustrates the operation of the Geo-Relock Key function **900** with reference to Table 1. The Geo-Relock Key function **900** receives five inputs, including: (1) Shape Parm In **902**; (2) Key ID In **904**; (3) Cipher Key In **906**; (4) Location ID Out **908**; and (5) Key ID Out **910**. The Geo-Relock Key function **900** also receives a GPS signal **920**. The Geo-Relock Key function **900** produces two outputs, including: (1) Shape Parm Out **912**; and (2) Cipher Key Out **914**. The Geo-Relock Key function **900** accesses the Geo-Unlock Key function **820** (described above) and the Geo-Lock Key function **800** (described above). The Geo-Unlock Key function **820** decrypts the Cipher Key In **906** using Shape Parm In **902** and Key ID In **904** in order to recover the Data Encrypting Key **524**. Then, the Geo-Lock Key function **800** re-encrypts Data Encrypting Key **524** using the new location value as determined by Location ID Out **908** and Key ID Out **910**. It should be noted that the values for Key ID In and Key ID Out could be the same or different depending on whether a new key encrypting key **307***a* is to be used in the process. Similarly, the location values could be the same or different, depending on whether decryption is to take place at the same or different location.

FIG. **10** illustrates the operation of the Geo-Relay Encrypt function **1000** with reference to Table 1. The Geo-Relay Encrypt function **1000** has inputs n **1002**, Location ID [j] **1004***j*, Key ID [j] **1006***j*, Location ID [n] **1004***n*, Key Id [n] **1006***n*, and Plaintext **518**. The input n **1002** corresponds to the total number of sites the data is to pass through on its way to a final receiver (i.e., the nth site) and j is the set of all integers from 1 to n−1. Thus, for every one of the 1 through n−1 receiver sites, there is a corresponding Location ID [j] and Key ID [j], and for the nth receiver site there is a Location ID [n] and Key ID [n]. As a result, the Geo-Relay Encrypt function **1000** will output Shape Parm [j] **1010***j* (namely, Shape Parm [1], Shape Parm [2], . . . Shape Parm [n−1]), Shape Parm [n] **1010***n*, Cipher Key **1008**, IV **1012**, and Ciphertext **520**. The Geo-Relay Encrypt function **1000** accesses the Geo-Encrypt function **700** (described above with respect to FIG. **7**) and the Geo-Lock Key function **800** (described above with respect to FIG. **8**). The Geo-Lock Key function **800** is embedded in a loop so that it is executed n−1 times, as will be further described below.

The Geo-Relay Encrypt function **1000** accesses the Geo-Encrypt function **700** to encrypt the Plaintext **518** and yield Ciphertext **520** substantially as described above with respect to FIG. **7**. The Data encrypting key generated as part of that process is locked using the Geo-Lock Key function **800** with inputs Location ID [n] **1004***n* and Key ID [n] **1006***n* to yield Cipher Key **1008**, Shape Parm [n] **1010***n*, and IV **1012**. The Cipher Key **1008** is then used as the Data encrypting key input in a loop in which the Geo-Lock Key function **800** is executed n−1 times. The loop begins at step **1020** by initializing a counter by setting j equal to n−1. At step **1022**, the counter is tested to determine whether j<1, i.e., a condition indicating that the end of the loop has been reached. If the end condition is met, the Geo-Relay Encrypt function **1000** is terminated. Conversely, if the end condition has not been met, the Geo-Lock Key function **800** is accessed with inputs Location ID [j] **1004***j* and Key ID [j] **1006***j* to yield a new Cipher Key **1008** and Shape Parm [j] **1010***j*. The counter j is then decremented at step **1024**, and the loop returns to step **1022** whereupon the end condition for the loop is again tested and the Geo-Lock Key function **800** again accessed if the end condition is not met. With each decrement of the counter, another layer of encryption is added to the Cipher Key **1008**. When the end condition for the loop is finally met, and the Geo-Relay Encrypt function **1000** terminated, the final Cipher Key **1008** is passed with the n−1 values of Shape Parm [j] **1010***j*, Shape Parm [n] **1010***n*, Ciphertext **520**, and IV **708** to the first relay station (e.g., distributor device). The first relay station will use the Geo-Unlock Key function **820** with Shape Parm [1] and Key ID [1] to remove the first layer of encryption from Cipher Key **1008**, the next station will use Shape Parm [2] and Key ID [2] to remove the second layer of encryption from Cipher Key **1008**, and so forth. Finally, the end relay station will produce the final Cipher Key after performing its unlock. Assuming the final Cipher Key has been properly passed through all relay stations and in the pre-determined order, the Ciphertext **520** can be decrypted.

A preferred embodiment of the invention also includes a set of functions for managing secret key encrypting/decrypting keys in the key tables when the keys are used with private-key cryptography. The functions provide for the creation, replacement, deletion, and distribution of the keys, using geo-encryption and geo-decryption for the distribution. It should be appreciated that the keys themselves can be distributed using either private-key cryptography or public-key cryptography with the geo-encryption and geo-decryption functions. It should also be appreciated that somewhat different functions are needed to manage the public and private keys used with public-key cryptography, in particular any public-key encrypting keys, private-key decrypting keys, private signature keys, and public signature validation keys. A preferred embodiment of this invention uses existing methods to manage these keys, using the key table for storage of the keys. It should be further appreciated that if public-key cryptography is used exclusively for key management, then the functions described herein to manage keys for private-key cryptography would not be required. It should also be appreciated that a combination of public-key and private-key cryptography could be used for key management.

Turning now to the management of secret key encrypting/decrypting keys used with private-key cryptography, every key in the key table of a producer device **300**, administrator device **310**, distributor device **320**, or receiver device **400** is owned by a particular provider. The provider can be a producer, distributor, administrator or any other entity that provides encrypted data. It should be appreciated that administrators are special providers having administrative control over keys. It should be further appreciated that each user of the present invention may further own one or more keys in a given key table to handle their specific needs. In an embodiment of the invention, a key owned by a particular provider is stored in the key table of the provider's device **300**, **310**, **320** so that the provider can use it to encrypt data or keys. Providers can add new keys to their own devices **300**, **310**, **320** and to the devices of others, although they may be limited in the total number of keys that can be added to any particular device. Providers also can change and delete any key they own in any device.

When a new provider is added to the network, the administrator device **310** will create one or more keys for the provider that can be used with each device that could receive encrypted data from that provider. Some of these keys may be unique to the devices and will be owned by the provider. The keys will be loaded into the key tables of the producer devices **300**, administrator device **310**, distributor devices **320**, and/or receiver devices **400** that are to receive encrypted data from that provider. The keys will be transmitted remotely to the devices if the devices are already in use in the field. In one embodiment of the invention, the administrator device **310** can change and delete any key in the key table of any other device even if it does not own the key. In another embodiment, the administrator device **310** cannot change or delete keys that it does not own. It should be appreciated that if public-key cryptography is used for key management, it is not necessary for the administrator device **310** to create and distribute keys on behalf of the provider as described above. Instead, a provider can communicate with any other device using the public key of that device.

The functions described below support management of the secret key encrypting/decrypting keys in key tables as shown in Table 1. As previously noted, these keys are used with private-key cryptography, but may be distributed using either public-key or private-key cryptography. In particular, the functions Create Key, Replace Key, and Delete Key are used to manage a provider's own secret keys in its own device. An Export Key function is used to obtain a Key Record from the provider's key table and geo-encrypt it so that the secret key can be securely exported from the provider device **300**, **310**, **320** and transmitted to another device. Finally, the functions Import New Key, Import Replacement Key, and Import Deletion Key are used in remote devices to handle the import of a previously exported key from another device and update its corresponding key table. In a preferred embodiment of the invention, public-key cryptography is used to authenticate the entity requesting a change in the key table of another device. This ensures that providers can only add, change, and delete keys that they own. The preferred embodiment uses a strong public-key signature algorithm for this purpose, such as RSA or DSA with keys of 2,048 bits or more.

As listed in Table 1, the Create Key function is used to create a new key that is added to a key table. The Create Key function receives as an input a Key ID. The PRNG sub-function may be used to generate a random Key Value. Then, a Key Record is created using the Key Id and the randomly generated Key Value. This newly created Key Record is then added to the key table of the device. Similarly, the Replace Key is used to replace the Key Value corresponding to a Key ID with a new value in a key table. The Replace Key function receives as an input the Key ID, and retrieves the Key Record corresponding to the Key ID from the key table. Then, the Key Value in the Key Record is replaced with a new value generated by the PRNG sub-function. For some applications, it may be desirable to provide a Delete Key function that deletes particular keys from a key table of a device. The Delete Key function receives as an input a particular Key ID in order to delete the corresponding key from the key table.

FIG. **11** illustrates the operation of the Export Key function **1100** with reference to Table 1. The Export Key function **1100** is performed by a provider device **300**, **310**, **320** in order to export one of its own keys to one or more other devices at specified locations so that the provider can use the key to communicate securely with these other devices. As listed in Table 1, the Export Key function **1100** has three inputs, including: (1) Key ID **505**; (2) Location ID **140**; and (3) Export Key ID **1102**. These inputs are used by the Export Key function **1100** in order to geo-encrypt the Key Record corresponding to Key ID in the device's key table. This encryption is done using Location ID **140** and the key identified by Export Key ID **1102**. As a result, a Cipher Key Record **1112** is produced along with a corresponding Cipher Key **526**, IV **708**, and Shape Parm **509**. In a preferred embodiment, the Export Key function **1100** signs the Cipher Key Record **1112** using a private key **308** owned by the provider that is stored in the key table of the provider along with other keys. The private key **308** includes the Provider ID in the key ID field and Priv Key Value in the key value field. As a result, a unique Signature **1116** is generated for the Cipher Key Record **1112**.

The Get Key Record sub-function **1110** will first retrieve the Key Record **307** corresponding to the key identified by Key ID **505** from a key table **306** of the device. As described previously, the Key Record **307** includes a specific Key ID and a Key value. The Geo-Encrypt function **700** is accessed to geo-encrypt the retrieved Key Record **307** using the Location ID **140** and Export Key ID **1102**. It should be appreciated that in this context the Key Record **307** corresponds to the Plaintext being geo-encrypted in the foregoing description with reference to FIG. **7**. This results in a Cipher Key Record **1112** that comprises the geo-encrypted Key Record **307**, along with a corresponding Cipher Key **526**, IV **708**, and Shape Parm **509**. The Sign sub-function **1114** is used to digitally sign the Cipher Key Record **1112** using the private key **308** stored in the key table of the device, and thereby provide the Signature **1116**. In a preferred embodiment, the Sign sub-function **1114** uses public-key cryptography, as noted above.

The Import New Key function **1150** is also shown in FIG. **11** with reference to Table 1. The Import New Key function **1150** is performed by a provider device **300**, **310**, **320** or receiver device **400** in order to import a key from another device in order to communicate securely with the other device. As listed in Table 1, the Import New Key function **1150** has seven inputs, including: (1) Shape Parm **509**; (2) Export Key ID **1102**; (3) Cipher Key **526**; (4) IV **708**; (5) Cipher Key Record **1112**; (6) Provider ID **1152**; and (7) Signature **1116**. The Cipher Key Record **1112** is decrypted using the key identified by Export Key ID **1102** and Shape Parm **509**.

More specifically, the Cipher Key Record **1112** is geo-decrypted using the Geo-Decrypt function **720** with Shape Parm **509**, Export Key ID **1102**, Cipher Key **526**, IV **708**, GPS location signal **727**, and Cipher Key Record **1112** as inputs to recover the Key Record **307**. A Provider ID Verification sub-function **1160** will then determine whether the Provider ID **1152** corresponds to either the Owner ID of the deciphered Key Record **307** or a Geo-encryption Key Authority (GKA) (i.e., an accepted key authority). If the Provider ID **1152** corresponds to one of these, i.e., the Owner ID or the GKA, then the Signature **1116** for the Key Record **307** is validated using a Check Signatures sub-function **1170**. The Check Signatures sub-function **1170** validates the Signature **1116** for Key Record **307** using the public key associated with the Provider ID, which would be obtained from the key table using Provider ID **1152** and possibly other information to identify the key. If the Signature **1116** proves to be valid, the Key Record **307** is added to the key table **406** by sub-function **1166**. Conversely, if the Provider ID Verification sub-function **1160** determines that the Provider ID **1152** corresponds to neither the Owner ID of the deciphered Key Record **307** or the GKA, the key table **406** is not updated. It should be noted that the public key associated with Provider ID **1152** might itself be validated using a certificate stored with the key in the key table or obtained using any of several methods without altering the scope and spirit of the invention.

The Import New Key function allows administrator devices **310** to add any key in a key table, including those it does not own. In a preferred embodiment that does not use public-key cryptography for key distribution, this capability of administrator devices **310** is necessary for distributing keys used by new provider devices **300**, **320** to communicate with receiver devices **400**. If the conditions described above are met, then the Import New Key function updates the key table to include the new Key Record **307**. Similarly, the Import Replacement Key function allows administrator devices **310** to change any key in a key table, including those it does not own. Namely, the Import Replacement Key function updates the key table by replacing the old Key Record corresponding to a particular Key ID with a new one (i.e., the one just imported). The purpose of giving administrator devices **310** this capability is so that they can handle a situation where a provider loses its keys or has its keys sabotaged in some way. It may alternatively be desirable in some circumstances to deny administrator devices **310** this capability. The Import Deletion Key function allows administrator devices **310** to delete any key in a key table, including those it does not own. The Import Deletion Key function updates the key table by deleting the Key Record corresponding to a particular Key ID. The purpose of giving administrator devices **310** this capability is so that they can clear out the keys owned by a defunct provider. It may alternatively be desirable in some circumstances to deny administrator devices **310** this capability.

In an alternative embodiment of the invention, digital information is associated with the location identity attribute **140** by encrypting the digital information using a location-based key. Particularly, a random data encrypting key is generated as described above, and a location value is derived from a location identity. The random data encrypting key and the location value are combined together using an exclusive-OR operation to provide a location-based key. The location-based key is used to encrypt the digital information. The random data encrypting key is encrypted using a key encrypting key, and the encrypted random data encrypting key and the encrypted digital information is communicated to the receiver. The receiver decrypts the random data encrypting key, determines the location value, and takes the exclusive-OR of the two numbers together to recover the location key. The digital data can then be decrypted using the recovered location key. A drawback of this alternative approach is that it is not well suited to re-locking or relay encryption because the digital data is encrypted using location information. Hence, the data itself would have to be re-encrypted, and not just the key. In applications in which the data is relatively short, then re-encrypting the data may be acceptable.

The functions described above can be used to restrict access to data that is transmitted over networks and telecommunications systems as well as data that is stored on a digital medium. As noted earlier, the data can be of any type and any form. Access to the data may be controlled for several reasons. For example, the data could be copyright-protected, classified, or sensitive. The following describes exemplary methods for using these functions to restrict access to transmitted and stored data when private-key cryptography is used for key distribution. In this description, it should be appreciated that references are made with respect to various functions listed in Table 1 along with their corresponding flow charts provided in FIGS. **7**–**11**. These methods may be used to support a variety of applications. For example, they can be used to support the secure distribution of movies, television programs, lectures, documents, and other types of data. These methods allow a producer or distributor of data to limit access to the data. Within this context, receivers may include customers or subscribers. It should be appreciated that different methods may be used if public-key cryptography is used for key management exclusively or in combination with private-key cryptography.

In order for a provider to send encrypted data to a receiver, both the provider device **300**, **310**, **320** and the receiver device **400** must share a common secret key encrypting/decrypting key in their respective key tables. This key is owned by the provider, thereby allowing the provider to change it or delete it as desired. It should be noted that the key is not actually used to encrypt the data. Rather, it is used with location information to encrypt a random data encryption key. Initially, both the provider devices **300**, **310**, **320** and the receiver device **400** are initialized with a secret key that is specific to the administrator device **310**. These keys are loaded into the respective key tables of provider devices **300**, **310**, **320** and receiver device **400** at the time the devices are produced.

As previously described, the first step is for the administrator device **310** to create a key that is owned by the provider and can be used by the provider to communicate with the receiver. Letting Provider ID denote the identity of the provider, administrator device **310** first performs the operation Create Key with input Key ID, where Key ID=(Provider ID, Key Name) for some Key Name. This operation may be performed at the request of the provider. The effect of the Create Key operation is that a new secret key is created with this Key ID. A record with the key is added to the key table **316** of the administrator device **310**. Next, the administrator device **310** performs the operation Export Key with inputs Key ID, Provider Location ID, and Provider Export Key ID, where Key ID is the same as before, Provider Location ID is the location of the provider device **300**, **320** and Provider Export Key ID is the identifier of the key shared by administrator device **310** and the provider device **300**, **320**. This will yield values Provider Shape Parm, Provider Cipher Key, IV, Provider Cipher Key Record, and Signature, which administrator device **310** transmits to the provider device **300**, **320**. Upon receipt, the provider devices **300**, **320** then perform the function Import New Key with inputs Provider Shape Parm, Provider Export Key ID, Provider Cipher Key, IV, Provider Cipher Key Record, and Signature. The purpose of this function is to decrypt Provider Cipher Key Record in order to produce a plaintext Key Record, to validate that the Key Record was signed by administrator device **310**, and then to insert the record into the key table of the device.

In addition, the administrator device **310** exports the key in a form that can be decrypted by the receiver device **400**. In particular, the administrator device **310** performs the function Export Key with inputs Key ID, Receiver Location ID, and Receiver Export Key ID, where Key ID is the same as before, Receiver Location ID is the location of the receiver device **400**, and Receiver Export Key ID is the identifier of a key shared by administrator device **310** and the receiver device **400**. This will yield the values Receiver Shape Parm, Receiver Cipher Key, IV, Receiver Cipher Key Record, and Signature, which the administrator device **310** transmits to the receiver device **400**. Upon receipt, the receiver device **400** then performs the function Import New Key with inputs Receiver Shape Parm, Receiver Export Key ID, Receiver Cipher Key, IV, Receiver Cipher Key Record, and Signature. The purpose of this function is to decrypt Cipher Key Record in order to produce a plaintext Key Record, to validate that the administrator device **310** signed the Key Record, and then to insert the record into the device's key table.

If the provider devices **300**, **320** request that the secret key be shared with multiple receiver devices **400**, perhaps even all receiver devices **400**, then the administrator device **310** exports the secret key to each such receiver device **400** separately using the unique key and location of each receiver device **400**. Alternatively, the administrator device **310** can export the secret key to all receiver devices **400** simultaneously if the devices have a common key that is shared with the administrator device **310**. The location used for this would be large enough to include all the receiver devices **400** that are authorized to receive data from this particular provider device **300**, **320**. It could be, for example, a universal location that encompasses the entire world. Alternatively, if a provider device **300**, **310** is only authorized to send data to receiver devices **400** in certain locations, then the administrator device **310** could set up the keys in such manner that the provider device **300**, **310** does not have a shared key with receiver devices **400** outside of these locations. As new receiver devices **400** join the system, the key can be exported to them accordingly. This approach for establishing a secure key can be used for any pair of entities, for example, a producer device **300** and a receiver device **400**, or a producer device **300** and a distributor device **320**, or a distributor device **320** and a receiver device **400**, or two distributor devices **320**.

Once a provider device **300**, **320** has a shared key with a receiver device **400** or with multiple receiver devices **400**, it can create and export keys of its own to these receiver devices **400** using the same technique used by the administrator device **310** to create and export keys. For example, a cable-TV company might create a monthly key for paid subscribers using the Create Key function. This key would be exported from its device using the Export Key function and sent to paid subscribers. Then, each month the key would be replaced with a new one using the Replace Key function. The new key would be exported with the Export Key function and sent to paid subscribers, who would receive and install it with the Import Replacement Key function. Subscribers who failed to pay would not get the new key, and, therefore, would be unable to decrypt future programs.

As another example, a provider device **300**, **320** might issue daily keys, identified with key names such as Monday, Tuesday, and so forth. It would issue the key for a particular day at the beginning of the day. The daily keys could be exported under longer-term keys such as monthly keys or individual receiver device **400** keys. Each weekly key would be good for seven days, and would be replaced when that period ends.

As a third example, a provider device **300**, **320** might issue keys that are associated with classification levels. For example, the Key Names might be “secret”, “confidential”, and “unclassified”. Secret keys would be issued to receiver devices **400** that are cleared at the “secret” level, “confidential” keys to receiver devices **400** that are cleared at the “confidential” or “secret” level, and “unclassified” keys to all receiver devices **400** allowed to receive data from the provider device **300**, **320**. Data that is classified “secret” would be enciphered using a Location Key derived from location and the secret key. “Confidential” and “unclassified” data would be handled in a similar manner.

The administrator device **310** can at any time replace one of its own keys using the Replace Key function with input Key ID. This function will put a new secret Key Value in its key table record for that Key ID. The administrator device **310** then exports the key to provider devices **300**, **320** and receiver devices **400** using it in the same manner as the original key that was exported. At the receiving end, either the provider device **300**, **320** or receiver device **400** will then use the Import Replacement Key function to import this key.

Once a secret key is established between a producer device **300** and a receiver device **400**, the producer device **300** can transmit data to the customer at a specific location in such a manner that the data is not accessible either at other locations or by receiver devices **400** lacking the key. First, the producer device **300** performs the Geo-Encrypt function with inputs Location ID, Key ID, and Plaintext, where Plaintext is the digital data, Location ID identifies the location of the customer(s), and Key ID identifies the shared key as before. This produces the values Shape Parm, Cipher Key, IV, and Ciphertext, where Ciphertext is the Plaintext encrypted under a random data encrypting key and Cipher Key is the encryption of the data encrypting key using the location specified by Location ID and the key specified by Key ID. These values are transmitted to one or more receiver devices **400** along with the Key ID. The intended receiver devices **400** would all share a location identified by Location ID.

The receiver devices **400** at the specified location can decrypt the data by performing the Geo-Decrypt function with inputs Shape Parm, Key ID, Cipher Key, IV, and Ciphertext. If the location of the receiver device **400** is not correct, or if the receiver device **400** does not have the key identified by Key ID, the decryption will fail. If the receiver device **400** is implemented with a Geo-Decrypt function that destroys the Cipher Key when decryption fails, the Ciphertext will henceforth become undecipherable.

A producer device **300** can transmit the same data to multiple receiver devices **400** at different locations with different secret keys without the need to re-encrypt the data. Instead, it suffices to re-lock the key under the different locations and keys. The following shows the method for doing this when there are three receiver devices **400**. First, the producer device **300** geo-encrypts the Plaintext for the first receiver device **400** using the Geo-Encrypt function with inputs Location ID[1], Key ID[1], and Plaintext. This function produces the results Shape Parm [1], Cipher Key [1], IV, and Ciphertext. These values along with Key ID [1] are transmitted to the first receiver device **400**. Next, Cipher Key [1] is re-locked with the location and secret key of the second receiver device **400** using the Geo-Relock function with inputs Shape Parm [1], Key Id [1], Cipher Key [1], Location ID [2], and Key ID [2]. This function produces the results Shape Parm [2] and Cipher Key [2]. These values along with Key ID [2], IV, and Ciphertext are transmitted to the second receiver device **400**.

Cipher Key [1] is then also re-locked with the location and secret key of the third receiver device **400** using the Geo-Relock Key function with inputs Shape Parm [1], Key ID [1], Cipher Key [1], Location ID [3], and Key ID [3]. This function produces the results Shape Parm [3] and Cipher Key [3]. These values along with Key ID [3], IV and Ciphertext are transmitted to the third receiver device **400**. Each of the three receiver devices **400** then uses the Geo-Decrypt function **720** to decrypt the common Ciphertext. It should be appreciated that this method can be extended to any number of receiver devices **400**. Furthermore, if there are multiple receiver devices **400** at a common location and with a common secret key, they can be sent the same values.

A method for securing data distribution from a producer device **300** to a receiver device **400** via a distributor device **320** is similar to the preceding method except that the producer device **300** does not distribute its data directly to the receiver devices **400**. Instead, the data is forwarded to a distributor device **320**, which in turn forwards it on to appropriate receiver devices **400**. The distributor device **320** re-encrypts the data (actually, the key) for transmission to these receiver devices **400**. Initially, the producer device **300** and distributor device **320** share a secret key that is owned by the producer.

In addition, the distributor device **320** and receiver devices **400** share a key that is owned by the distributor. Within this embodiment, it should be appreciated that the producer device **300** does not need to share a key with the receiver devices **400** or even know the identity of the receivers.

The producer device **300** begins this process by geo-encrypting the data for transmission to the distributor device **320**. This is done by performing the Geo-Encrypt function with inputs Distributor Location ID, Distributor Key ID, and Plaintext, where Distributor Key ID is the identifier of the key that is owned by the producer and shared with the distributor device **320** and Distributor Location ID is the location of the distributor device **320**. The result of this operation yields the values Distributor Shape Parm, Distributor Cipher Key, IV, and Ciphertext. The producer device **300** then transmits these values to the distributor device **320** along with Distributor Key ID. The distributor device **320** then performs the Geo-Relock Key function with inputs Distributor Shape Parm, Distributor Key ID, Distributor Cipher Key, Receiver Location ID, and Receiver Key ID, where Receiver Key ID is the identifier of the key that is owned by the distributor and shared with the receiver device **400** and Receiver Location ID is the location of the receiver device **400**. The result of this operation is a value for Receiver Shape Parm and Receiver Cipher Key. These values are transmitted to the receiver device **400** along with Receiver Key ID, IV, and Ciphertext. In order to yield Plaintext, the receiver device **400** then performs the Geo-Decrypt function with inputs Receiver Shape Parm, Receiver Key ID, Receiver Cipher Key, IV, and Ciphertext. The advantage of this approach is that the producer does not need to know anything about the receivers. Moreover, the distributor **320** manages the receiver devices **400**. Such an embodiment could be attractive for a small producer **300**. For example, a distributor could keep track of sales of the producer's data to receivers, and then pass along the sales income, minus a service fee, to the producer. Of course, other arrangements are also possible. For example, the producer could license use of its data by the distributor without regard to individual sales.

With the preceding method, a distributor may readily decrypt and access plaintext. The distributor could then re-encrypt the data for any receiver device **400** to which it has access regardless of the producer's intentions. With the implementation of a relay encryption function this is not possible because the producer device **300** locks the data encryption key first with a location and key that is shared with the receiver device **400** and then with a location and key that is shared with the distributor device **320**. The distributor device **320** can strip off its own encryption layer, but not the receiver device's **400** encryption layer, so the data can never go to a receiver device **400** other than the one authorized by the producer device **320**. With relay encryption, the producer can also be sure that the data will pass through the distributor device **320** before it is decrypted, as the receiver device **400** cannot remove the encryption layer of the distributor device **320**.

In order to achieve this task, the producer device **300** first performs the Geo-Relay Encrypt function with inputs n, Distributor Location ID, Distributor Key ID, Receiver Location ID, Receiver Key ID, and Plaintext, where it is understood that n=2. This operation yields the values Distributor Shape Parm, Receiver Shape Parm, Cipher Key, IV, and Ciphertext. These values are transmitted to the distributor device **320** along with Distributor Key ID and Receiver Key ID. The distributor device **320** then uses the key identified by Distributor Key ID to strip off its layer of key encryption on Cipher Key. This is done by performing the Geo-Unlock Key function with inputs Distributor Shape Parm, Distributor Key ID, and Cipher Key. This operation yields New Cipher Key, which is transmitted to the receiver device **400** along with Receiver Key ID, Receiver Shape Parm, IV, and Ciphertext. Finally, the receiver device **400** deciphers the Ciphertext by performing the Geo-Decrypt function with inputs Receiver Shape Parm, Receiver Key ID, New Cipher Key, IV, and Ciphertext. It should be noted that the above method could also be used to relay data through multiple distributor devices **320** instead of just one.

With relay encryption, a producer maintains control over access to its data, while still benefiting from the use of a distributor. Such an embodiment could be attractive to large producers. A producer may, for example, use relay encryption to control the distribution of its data from multiple distributors. Within such embodiment, one distributor device **320** could be given encrypted data destined for receiver devices **400** in one geographic region. A second distributor device **320** could then be given the same encrypted data, but with the data encryption key re-locked so as to be decipherable only by receiver devices **400** in a second region, and so on. Distributors owning the distribution rights of different geographic regions would thus be unable to infringe upon each other's regions.

In another embodiment, the Geo-Encrypt **700** and Geo-Decrypt **720** functions may be used by any provider device **300**, **310**, **320** to respectively encrypt and decrypt data that is stored by the provider. Within such embodiment, encryption and decryption are specific to the location of the provider device **300**, **310** and a secret key stored in the provider's key table. In order to achieve this task, the provider device **300**, **310**, **320** first encrypts the data by performing the Geo-Encrypt function with inputs Location ID, Key ID, and Plaintext, where Location ID identifies the location of the provider device **300**, **310**, **320** and Key ID identifies the key of the provider device **300**, **310**, **320**. This produces the values Shape Parm, Cipher Key, IV, and Ciphertext, which would then be stored in the ciphertext file along with Key ID. At a later time, the provider device **300**, **310**, **320** decrypts the data by performing the Geo-Decrypt function with inputs Shape Parm, Key ID, Cipher Key, IV, and Ciphertext, using the values obtained from the ciphertext file.

If the data is to be stored for an extended period, the Cipher Key might be relocked with a new key from time to time. Also, if the Key Value associated with this particular Key ID ever changes as the result of an Update Key operation, Cipher Key would have to be unlocked with the old value and re-locked with a new value before the old value is discarded. Otherwise, the data would become undecipherable.

In summary, by enabling location-based encryption and path-dependent encryption, the present invention has numerous advantages over the prior art. One such advantage is that it adds an additional layer of security to any encryption system. Not only does the recipient need access to a secret key, but the recipient also must be at a particular location in order to decrypt data. Another advantage pertains to the distribution of confidential materials where one of the parties in the communication cannot be trusted to maintain the confidentiality of the materials. The present invention uses a combination of location and key table keys, both of which can be implemented transparently to the user, to defeat the threat of disclosure by a user who cannot be trusted with the cryptographic keys. As previously described, the present invention may also be implemented to render digital information unusable if access is attempted that is invalid, by destroying or re-encrypting the digital information.

The present invention enables producers to actively control and participate in the encryption of their proprietary data, even after release from their protected domain, through their ability to own and control keys in receiver devices **400** and to multi-lock keys so that data can only be unlocked by a final receiver **400** and not by intermediate distributor devices **320**. Specifically, digital information can be encrypted in such a way that it can only be decrypted at the receiver device **400** if its transmission has followed a pre-defined path over the network **200**, passing through specific geographic locations. A unique method is provided by the present invention in which digital information can be encrypted in such a way that, as it moves from provider device **300**, **310**, **320** to final receiver device **400**, each distributor on the path to the target location must remove its lock from the cipher key. Final decryption is possible only after all locks have been removed.

Key management is often the weakness of a cryptographic system. The present invention addresses this weakness by allowing for the dynamic management of all keys over a network in a secure manner that is transparent to the user and by allowing for the use of public-key cryptography. Also, unlike DRM systems that require separate steps to access both the Ciphertext and the key or license required for decryption, the present invention uses a single digital data acquisition step.

Having thus described a preferred embodiment of a system and method for delivering encrypted information in a communication network using location identity and key tables, it should be apparent to those skilled in the art that certain advantages have been achieved. It should also be appreciated that various modifications, adaptations, and alternative embodiments thereof may be made within the scope and spirit of the present invention. The invention is further defined by the following claims.

What is claimed is:

1. A method for controlling access to digital information, comprising:

encrypting said digital information using a data encrypting key;

modifying the data encrypting key using location identity data that defines at least a specific geographic location to produce a location-modified data encrypting key;

encrypting said location-modified data encrypting key using a key encrypting key to produce an encrypted location-modified data encrypting key; and

communicating said encrypted location-modified data encrypting key and said encrypted digital information to a recipient device such that said encrypted digital information can be decrypted by the recipient only at said specific geographic location.

2. The method of claim **1**, wherein said location identity data further comprises at least a location value and a proximity value of said specific geographic location.

3. The method of claim **2**, wherein said location value defines a location of an intended receiver of said digital information.

4. The method of claim **3**, wherein said proximity value defines a zone that encompasses said location.

5. The method of claim **2**, wherein said location value further comprises at least one of a latitude, longitude, altitude and time dimension.

6. The method of claim **2**, wherein said location identity data further defines a universal location that encompasses the entire earth.

7. The method of claim **1**, further comprising identifying location of a receiver at which access to said digital information is sought.

8. The method of claim **7**, wherein said location identifying step further comprises recovering said location from a GPS receiver.

9. The method of claim **1**, wherein said location identity data further comprises a location value and a shape parameter, the shape parameter defining a shape of a region encompassing the specific geographic location.

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

decrypting said encrypted location-modified data encrypting key using a key decrypting key;

using a location value to recover said data encrypting key from said location-modified data encrypting key; and

decrypting said digital information using said data encrypting key.

11. The method of claim **10**, further comprising deriving said location value from a signal received by a GPS receiver and a shape parameter defining a shape of a region encompassing the specific geographic location.

12. The method of claim **10**, further comprising precluding ability to decrypt said encrypted digital information if said step of decrypting said encrypted digital information is attempted at other than said specific geographic location.

13. The method of claim **10**, further comprising precluding ability to decrypt said encrypted digital information if said step of decrypting said encrypted digital information is attempted without using said key decrypting key.

14. The method of claim **1**, wherein said digital information further comprises a secret key, and further comprising the step of distributing said secret key to an intended receiver.

15. The method of claim **1**, further comprising routing said encrypted digital information to an intended receiver through at least one distributor.

16. The method of claim **15**, wherein said routing step further comprises adding a layer of encryption of said data encrypting key for said at least one distributor.

17. The method of claim **1**, further comprising generating said data encrypting key using a pseudo-random number generator.

18. The method of claim **17**, wherein said step of generating said data encrypting key further comprises using GPS signals to partially seed said pseudo-random number generator.

19. The method of claim **1**, further comprising decrypting and recovering said data encrypting key from said encrypted location-modified data encrypting key using a key decrypting key and a location value, and re-encrypting said data encrypting key using at least one of a different location identity data and a different key encrypting key to produce a different encrypted location-modified data encrypting key.

20. The method of claim **1**, further comprising providing a key table used to store a plurality of keys including said key encrypting key.

21. The method of claim **20**, further comprising associating said plurality of keys with respective providers of said digital information.

22. The method of claim **20**, further comprising administering management of said plurality of keys in said key table.

23. The method of claim **22**, wherein said administering step further comprises adding, changing or deleting any one of said plurality of keys in said key table.

24. The method of claim **22**, wherein said key table is located with a remote device, and said administering step further comprises adding, changing or deleting any one of said plurality of keys in said key table remotely.

25. The method of claim **24**, wherein said administering step further comprises including a signature when adding, changing or deleting any one of said plurality of secret keys in said key table.

26. The method of claim **20**, wherein said step of providing a key table further comprises storing keys used for signing data and validating signatures.

27. An apparatus for controlling access to digital information, comprising:

a processor having memory adapted to store software instructions operable to cause said processor to perform the functions of:

encrypting said digital information using a data encrypting key;

modifying the data encrypting key using location identity data that defines at least a specific geographic location to produce a location-modified data encrypting key;

encrypting said location-modified data encrypting key using a key encrypting key to produce an encrypted location-modified data encrypting key; and

communicating said encrypted location-modified data encrypting key and said encrypted digital information to a recipient device such that said encrypted digital information can be decrypted by the recipient only at said specific geographic location.

28. The apparatus of claim **27**, wherein said location identity data comprises at least a location value and a proximity value of said specific geographic location.

29. The apparatus of claim **28**, wherein said location value defines a location of an intended receiver of said digital information.

30. The apparatus of claim **28**, wherein said location value further comprises at least one of a latitude, longitude, altitude and time dimension.

31. The apparatus of claim **28**, wherein said proximity value corresponds to a zone that encompasses said location.

32. The apparatus of claim **27**, wherein said processor is further operable to identify location of a receiver at which access to said digital information is sought.

33. The apparatus of claim **27**, further comprising a GPS receiver coupled to said processor.

34. The apparatus of claim **27**, wherein said location identity data further comprises a location value and a shape parameter, the shape parameter defining a shape of a region encompassing said specific geographic location.

35. The apparatus of claim **27**, wherein said digital information further comprises a secret key, and said processor is further operable to distribute said secret key to an intended receiver located at said specific geographic location.

36. The apparatus of claim **27**, wherein said processor is further operable to route said encrypted digital information to an intended receiver through at least one distributor.

37. The apparatus of claim **27**, further comprising a pseudo-random number generator operatively coupled to said processor to generate said data encrypting key.

38. The apparatus of claim **27**, wherein said processor is further operable to decrypt said encrypted location-modified data encrypting key, and re-encrypt said location-modified data encrypting key using at least one of a different location identity data and a different key encrypting key.

39. The apparatus of claim **27**, wherein said memory further comprises a key table used to store a plurality of keys including said key encrypting key.

40. The apparatus of claim **39**, wherein ones of said plurality of keys are associated with respective providers of said digital information.

41. The apparatus of claim **39**, wherein processor is further operable to add, change or delete any one of said plurality of keys in said key table.

42. The method of claim **39**, wherein said processor is further operable to provide a signature for authentication of one of said plurality of keys.

43. An apparatus for receiving digital information, comprising:

a processor having memory adapted to store software instructions operable to cause said processor to perform the functions of:

receiving encrypted digital information and an encrypted location-modified data encrypting key;

decrypting said encrypted location-modified data encrypting key using a key encrypting key to obtain a location-modified data encrypting key;

determining a location value that defines a specific geographic location of said apparatus;

extracting a data encrypting key from said location-modified data encrypting key using said location value; and

decrypting said encrypted digital information using said data encrypting key.

44. The apparatus of claim **43**, wherein said function of decrypting said encrypted digital information further comprises precluding ability to decrypt said encrypted digital information if decryption is attempted at other than said specific geographic location.

45. The apparatus of claim **43**, further comprising a GPS receiver coupled to said processor.

46. The apparatus of claim **43**, wherein said processor is further operable to re-encrypt said data encrypting key using at least one of a different location identity data and a different key encrypting key.

47. The apparatus of claim **43**, wherein said memory further comprises a key table used to store a plurality of keys including said key decrypting key.

48. The apparatus of claim **43**, wherein ones of said plurality of keys are associated with respective providers of said digital information.

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