



US009270464B2

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

(10) **Patent No.:** **US 9,270,464 B2**
(45) **Date of Patent:** ***Feb. 23, 2016**

(54) **METHODS FOR SECURE ENROLLMENT AND BACKUP OF PERSONAL IDENTITY CREDENTIALS INTO ELECTRONIC DEVICES**

9/3263 (2013.01); G06K 9/00885 (2013.01); G06Q 20/40145 (2013.01); H04L 63/0861 (2013.01)

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(58) **Field of Classification Search**

CPC ... G06F 21/32; H04L 63/0861; H04L 9/3231; H04L 9/0866; G06K 9/0085; G06Q 20/40145
See application file for complete search history.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

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4,993,068 A 2/1991 Piosenka et al.
5,053,608 A 10/1991 Senanayake

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

(Continued)

This patent is subject to a terminal disclaimer.

FOREIGN PATENT DOCUMENTS

JP 2002-73566 2/2002
WO WO 99/08238 2/1999

(Continued)

(21) Appl. No.: **14/445,853**

OTHER PUBLICATIONS

(22) Filed: **Jul. 29, 2014**

International Search Report for PCT/US2003/024472 dated Nov. 20, 2003, 2 pages.

(65) **Prior Publication Data**

US 2014/0344583 A1 Nov. 20, 2014

(Continued)

Related U.S. Application Data

(63) Continuation of application No. 13/849,985, filed on Mar. 25, 2013, now Pat. No. 8,826,031, which is a continuation of application No. 13/210,022, filed on Aug. 15, 2011, now Pat. No. 8,407,480, which is a

(Continued)

(51) **Int. Cl.**

G06F 11/30 (2006.01)
H04L 9/32 (2006.01)

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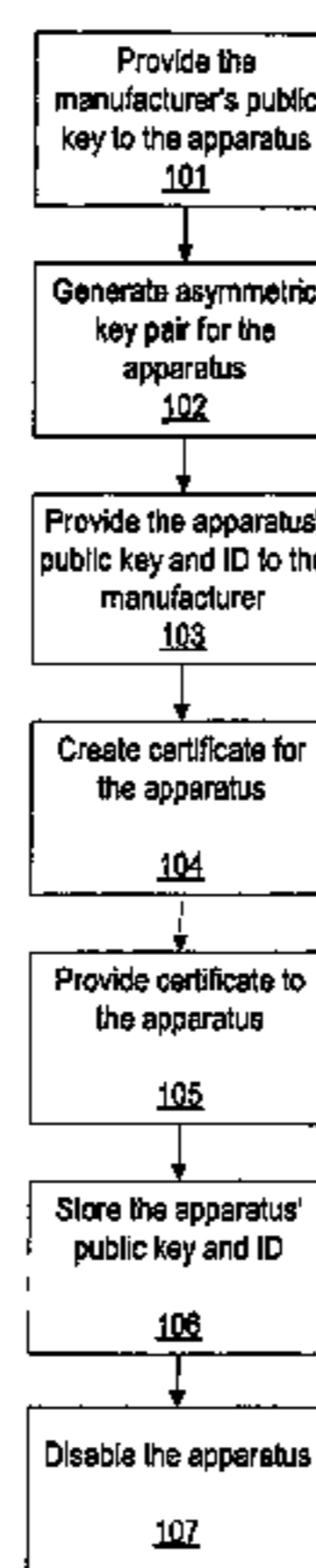
(52) **U.S. Cl.**

CPC **H04L 9/3231** (2013.01); **G06F 21/32** (2013.01); **H04L 9/3247** (2013.01); **H04L**

(57) **ABSTRACT**

A method and system for securely enrolling personal identity credentials into personal identification devices. The system of the invention comprises the manufacturer of the device and an enrollment authority. The manufacturer is responsible for recording serial numbers or another unique identifier for each device that it produces, along with a self-generated public key for each device. The enrollment authority is recognized by the manufacturer or another suitable institution as capable of validating an individual before enrolling him into the device. The enrollment authority maintains and operates the appropriate equipment for enrollment, and provides its approval of the enrollment. The methods described herein discuss post-manufacturing, enrollment, backup, and recovery processes for the device.

40 Claims, 4 Drawing Sheets



Related U.S. Application Data

continuation of application No. 12/560,254, filed on Sep. 15, 2009, now Pat. No. 8,001,372, which is a continuation of application No. 10/635,762, filed on Aug. 6, 2003, now Pat. No. 7,590,861.

(60) Provisional application No. 60/401,399, filed on Aug. 6, 2002.

(51) **Int. Cl.**

G06F 21/32 (2013.01)
G06K 9/00 (2006.01)
H04L 29/06 (2006.01)
G06Q 20/40 (2012.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,131,038 A 7/1992 Puhl et al.
 5,280,527 A 1/1994 Gullman et al.
 5,469,506 A 11/1995 Berson et al.
 5,473,692 A 12/1995 Davis
 5,481,265 A 1/1996 Russell
 5,526,428 A 6/1996 Arnold
 5,591,949 A 1/1997 Bernstein
 5,613,012 A 3/1997 Hoffman et al.
 5,615,277 A 3/1997 Hoffman
 5,659,616 A 8/1997 Sudia
 5,729,220 A 3/1998 Russell
 5,784,463 A 7/1998 Chen et al.
 5,805,719 A 9/1998 Pare, Jr. et al.
 5,838,812 A 11/1998 Pare, Jr. et al.
 5,870,723 A 2/1999 Pare, Jr. et al.
 5,872,848 A 2/1999 Romney et al.
 5,920,640 A 7/1999 Salatino et al.
 5,930,804 A 7/1999 Yu et al.
 5,952,641 A 9/1999 Korshun
 5,991,408 A 11/1999 Pearson et al.
 6,038,666 A 3/2000 Hsu et al.
 6,041,410 A 3/2000 Hsu et al.
 6,076,167 A 6/2000 Borza
 6,084,967 A * 7/2000 Kennedy et al. 380/247
 6,084,968 A 7/2000 Kennedy et al.
 6,154,879 A 11/2000 Pare, Jr. et al.
 6,167,517 A 12/2000 Gilchrist et al.
 6,181,803 B1 1/2001 Davis
 6,182,221 B1 1/2001 Hsu et al.
 6,185,316 B1 2/2001 Buffam
 6,201,484 B1 3/2001 Russell
 6,202,151 B1 3/2001 Musgrave et al.
 6,219,793 B1 4/2001 Li et al.
 6,256,737 B1 7/2001 Bianco et al.
 6,268,788 B1 7/2001 Gray
 6,282,649 B1 8/2001 Lambert et al.
 6,310,966 B1 10/2001 Dulude et al.
 6,317,834 B1 11/2001 Gennaro et al.
 6,353,889 B1 3/2002 Hollingshead
 6,356,753 B1 * 3/2002 Kolev et al. 455/411
 6,366,682 B1 * 4/2002 Hoffman et al. 382/115
 6,367,013 B1 4/2002 Bisbee et al.
 6,367,017 B1 4/2002 Gray
 6,397,198 B1 5/2002 Hoffman et al.
 6,446,210 B1 9/2002 Borza
 6,466,781 B1 10/2002 Bromba et al.
 6,484,260 B1 * 11/2002 Scott et al. 713/186
 6,487,662 B1 11/2002 Kharon et al.
 6,490,680 B1 12/2002 Scheidt et al.
 6,505,193 B1 1/2003 Musgrave et al.
 6,529,885 B1 3/2003 Johnson
 6,532,298 B1 3/2003 Cambier et al.
 6,581,161 B1 6/2003 Byford
 6,601,172 B1 7/2003 Epstein
 6,609,198 B1 8/2003 Wood et al.
 6,615,264 B1 9/2003 Stoltz et al.
 6,618,806 B1 9/2003 Brown et al.

6,636,973 B1 10/2003 Novoa et al.
 6,657,538 B1 12/2003 Ritter
 6,662,166 B2 12/2003 Pare, Jr. et al.
 6,668,332 B1 12/2003 McNeil
 6,671,808 B1 12/2003 Abbott et al.
 6,681,034 B1 1/2004 Russo
 6,719,200 B1 4/2004 Wiebe
 6,728,881 B1 4/2004 Karamchetty
 6,735,695 B1 5/2004 Gopalakrishnan et al.
 6,751,734 B1 6/2004 Uchida
 6,757,411 B2 6/2004 Chau
 6,765,470 B2 7/2004 Shinzaki
 6,766,040 B1 7/2004 Catalano et al.
 6,775,776 B1 8/2004 Vogt et al.
 6,786,397 B2 9/2004 Silverbrook et al.
 6,816,970 B2 11/2004 Morgan et al.
 6,819,219 B1 11/2004 Bolle et al.
 6,820,202 B1 11/2004 Wheeler et al.
 6,829,711 B1 12/2004 Kwok et al.
 6,832,317 B1 12/2004 Strongin et al.
 6,834,351 B1 * 12/2004 Kabenjian 726/9
 6,836,765 B1 12/2004 Sussman
 6,836,843 B2 12/2004 Seroussi et al.
 6,839,688 B2 1/2005 Drummond et al.
 6,844,660 B2 1/2005 Scott
 6,848,052 B2 1/2005 Hamid et al.
 6,850,147 B2 2/2005 Prokoski et al.
 6,850,252 B1 2/2005 Hoffberg
 6,853,739 B2 2/2005 Kyle
 6,853,988 B1 2/2005 Dickinson et al.
 6,857,073 B2 2/2005 French et al.
 6,862,443 B2 3/2005 Witte
 6,870,946 B1 3/2005 Teng et al.
 6,870,966 B1 3/2005 Silverbrook et al.
 6,871,193 B1 3/2005 Campbell et al.
 6,871,287 B1 3/2005 Ellingson
 6,871,784 B2 3/2005 Jayaratne
 6,876,757 B2 4/2005 Yau et al.
 6,877,097 B2 4/2005 Hamid et al.
 6,879,243 B1 4/2005 Booth et al.
 6,879,966 B1 4/2005 Lapsley et al.
 6,880,749 B1 4/2005 Green et al.
 6,880,750 B2 4/2005 Pentel
 6,883,709 B2 4/2005 Joseph
 6,886,096 B2 4/2005 Appenzeller et al.
 6,886,101 B2 4/2005 Glazer et al.
 6,886,104 B1 4/2005 McClurg et al.
 6,888,445 B2 5/2005 Gotfried et al.
 6,898,577 B1 5/2005 Johnson
 6,901,154 B2 5/2005 Dunn
 6,901,155 B2 5/2005 Xia et al.
 6,901,266 B2 5/2005 Henderson
 6,901,382 B1 5/2005 Richards et al.
 6,914,517 B2 7/2005 Kinsella
 6,957,185 B1 10/2005 Labaton
 6,957,337 B1 10/2005 Chainer et al.
 6,963,659 B2 11/2005 Tumey et al.
 6,985,502 B2 1/2006 Bunton
 6,990,444 B2 1/2006 Hind et al.
 7,024,562 B1 4/2006 Flink et al.
 7,028,191 B2 4/2006 Michener et al.
 7,035,442 B2 4/2006 Ha et al.
 7,069,444 B2 6/2006 Lowensohn et al.
 7,111,173 B1 9/2006 Scheidt
 7,287,158 B2 10/2007 Futamura et al.
 7,305,562 B1 12/2007 Bianco et al.
 7,310,734 B2 12/2007 Boate et al.
 7,590,861 B2 9/2009 Abdallah et al.
 7,613,659 B1 11/2009 Hoffman et al.
 7,788,501 B2 8/2010 Abdallah et al.
 8,001,372 B2 8/2011 Abdallah et al.
 8,055,906 B2 11/2011 Abdallah et al.
 8,127,143 B2 2/2012 Abdallah et al.
 8,407,480 B2 3/2013 Abdallah et al.
 2001/0001876 A1 5/2001 Morgan et al.
 2001/0034836 A1 10/2001 Matsumoto
 2002/0003892 A1 * 1/2002 Iwanaga 382/124
 2002/0018585 A1 2/2002 Kim
 2002/0023217 A1 2/2002 Wheeler et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2002/0026427 A1 2/2002 Kon et al.
 2002/0031230 A1 3/2002 Sweet et al.
 2002/0034319 A1 3/2002 Tumey et al.
 2002/0056043 A1 5/2002 Glass
 2002/0087857 A1 7/2002 Tsao et al.
 2002/0095586 A1 7/2002 Doyle et al.
 2002/0104006 A1 8/2002 Boate et al.
 2002/0104025 A1 8/2002 Wrench, Jr.
 2002/0129236 A1 9/2002 Nuutinen
 2002/0129251 A1 9/2002 Itakura et al.
 2002/0133716 A1* 9/2002 Harif 713/201
 2002/0174344 A1 11/2002 Ting
 2002/0186838 A1 12/2002 Brandys
 2003/0005310 A1 1/2003 Shinzaki
 2003/0089764 A1 5/2003 Meadow et al.
 2003/0097586 A1* 5/2003 Mok 713/200
 2003/0101349 A1 5/2003 Wang
 2003/0115475 A1 6/2003 Russo et al.
 2003/0115490 A1 6/2003 Russo et al.
 2003/0200257 A1 10/2003 Milgramm et al.
 2003/0233556 A1 12/2003 Angelo et al.
 2004/0015958 A1 1/2004 Veil et al.
 2004/0044627 A1 3/2004 Russell et al.
 2009/0031140 A1 1/2009 Abdallah et al.
 2009/0037745 A1 2/2009 Abdallah et al.

2009/0037746 A1 2/2009 Abdallah et al.
 2010/0005315 A1 1/2010 Abdallah et al.
 2012/0047370 A1 2/2012 Abdallah et al.

FOREIGN PATENT DOCUMENTS

WO 00/65770 11/2000
 WO WO 0192994 A2 12/2001
 WO WO2004/014017 A1 2/2004

OTHER PUBLICATIONS

European Search Report for European Patent Application No. 03767206.0 mailed Jul. 4, 2011, 3 pages.
 Schneier, Bruce, "Applied Cryptography: Protocols, Algorithms, and Source Code in C," Second Edition, 1996, John Wiley & Sons, Inc., pp. 31-34.
 Fumiko Komatsu, PKI Handbook, Japan, Soft Research Center Inc., Nov. 25, 2000, pp. 105-108.
 Isobe, Y et al., "Development of personal authentication system using fingerprint with digital signature technologies," Proceedings of the 34th Hawaii International Conference on System Sciences, Jan. 3, 2001, pp. 4039-4047.
 Davida, G. et al., "On enabling secure applications through off-line biometric identification," Security and Privacy, May 3, 1998. Proceedings of the 1998 IEEE Symposium, pp. 148-157.

* cited by examiner

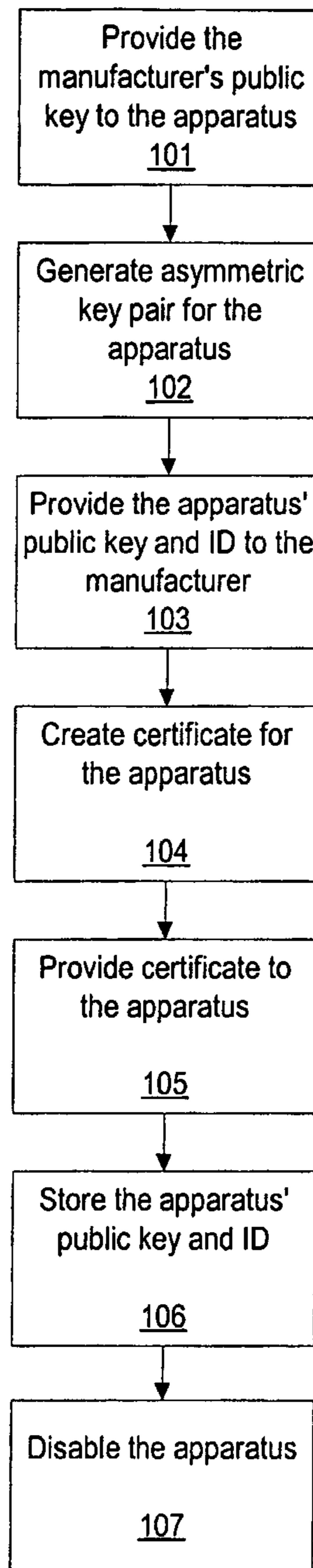


FIGURE 1

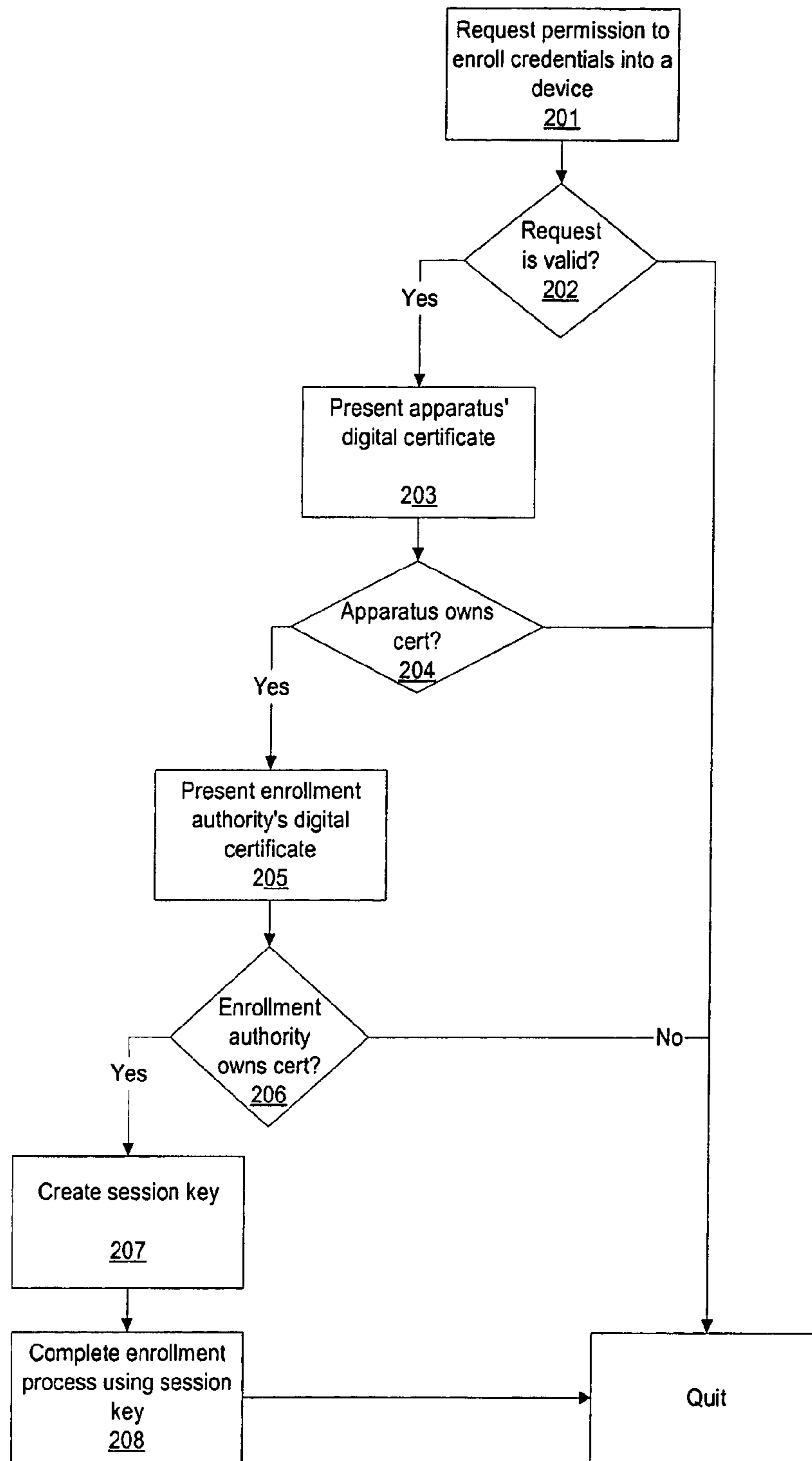


FIGURE 2

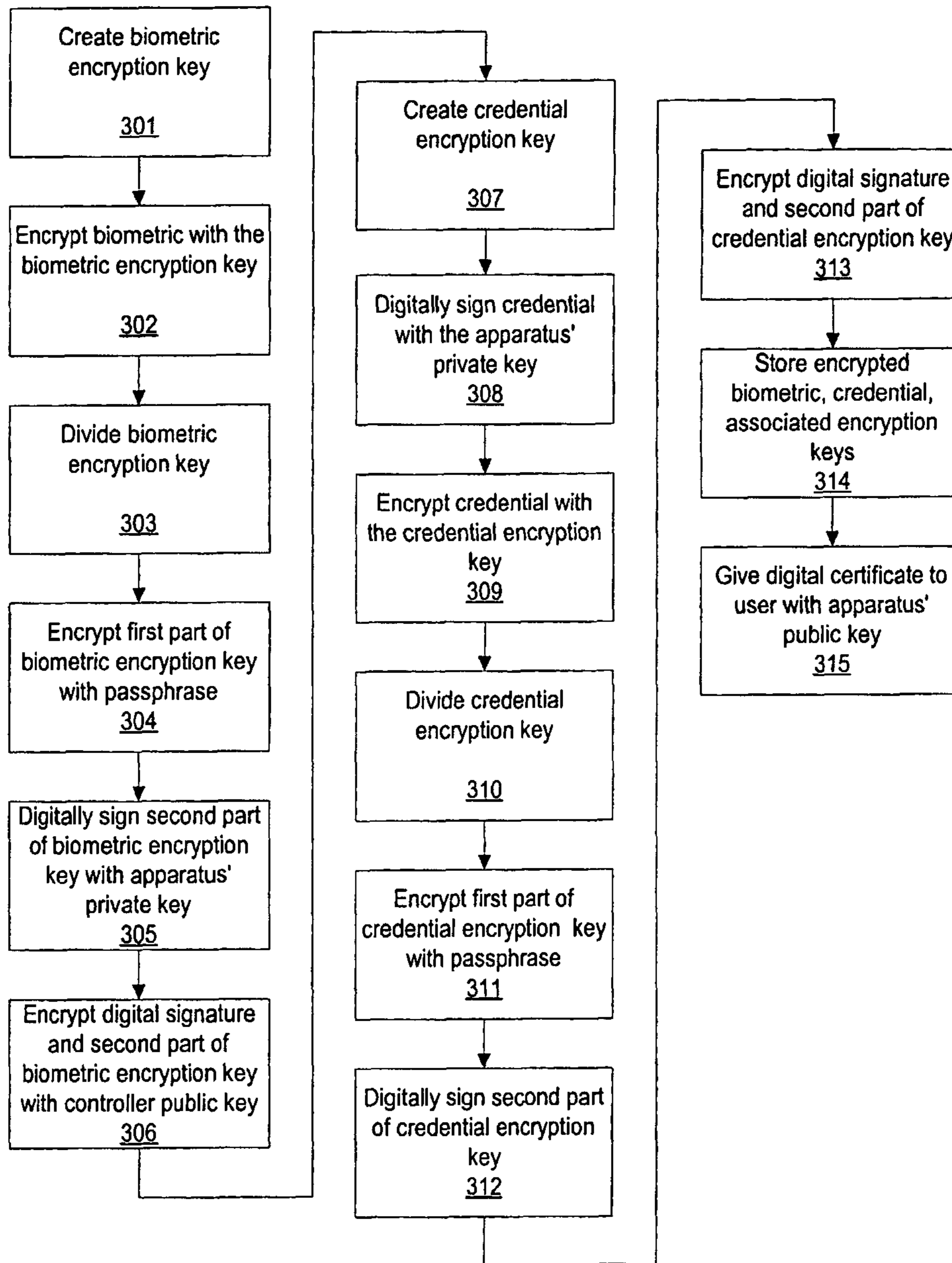


FIGURE 3

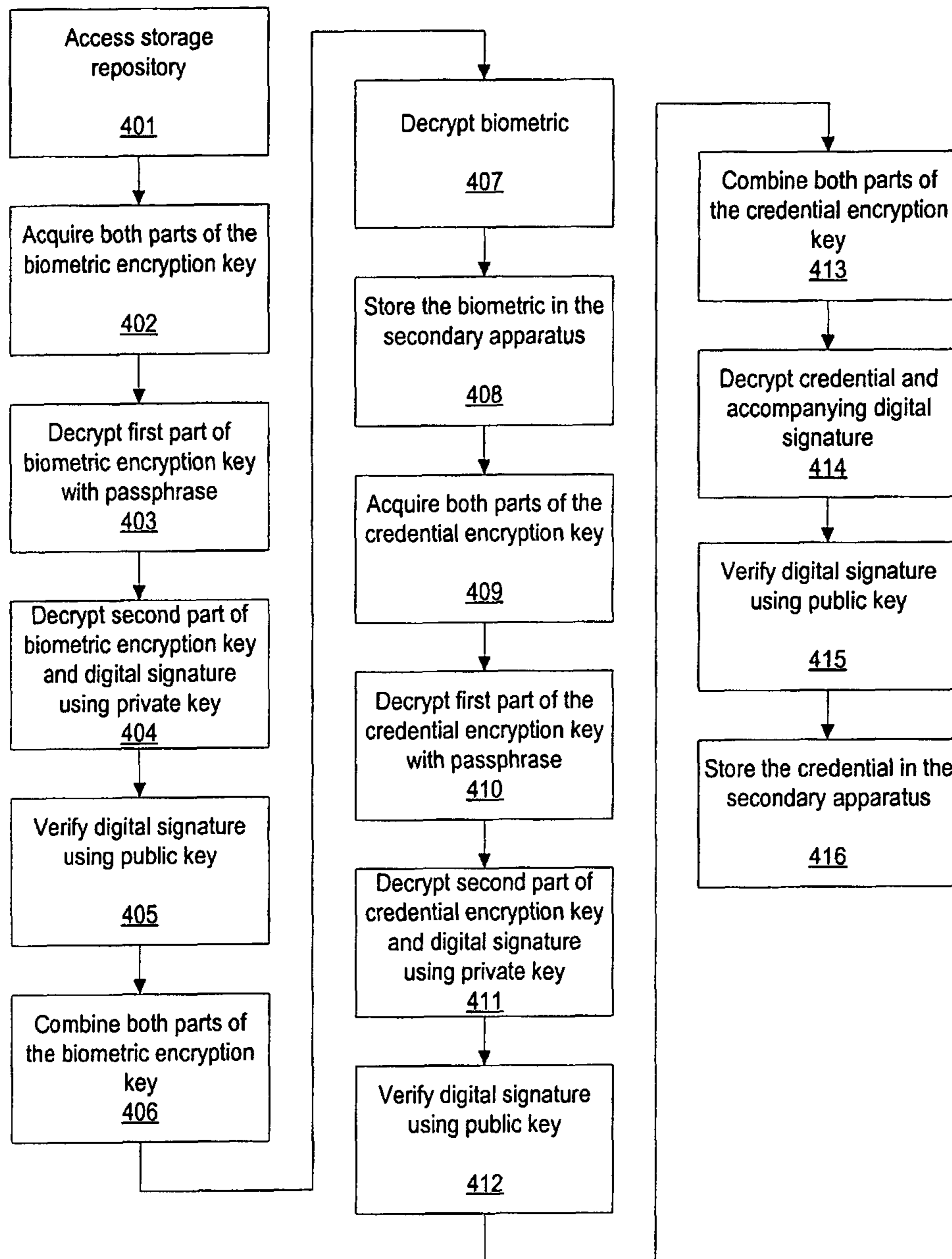


FIGURE 4

**METHODS FOR SECURE ENROLLMENT
AND BACKUP OF PERSONAL IDENTITY
CREDENTIALS INTO ELECTRONIC
DEVICES**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/849,985, filed on Mar. 25, 2013, entitled, "Methods for Secure Enrollment and Backup of Personal Identity Credentials Into Electronic Devices," which is a continuation of U.S. patent application Ser. No. 13/210,022, now U.S. Pat. No. 8,407,480, filed on Aug. 15, 2011, entitled, "Methods For Secure Enrollment And Backup Of Personal Identity Credentials Into Electronic Devices," which is a continuation of U.S. patent application Ser. No. 12/560,254, filed on Sep. 15, 2009, entitled "Methods For Secure Enrollment And Backup Of Personal Identity Credentials Into Electronic Devices," now U.S. Pat. No. 8,001,372, which is a continuation of U.S. patent application Ser. No. 10/635,762, filed on Aug. 6, 2003, entitled "Methods For Secure Enrollment And Backup Of Personal Identity Credentials Into Electronic Devices," now U.S. Pat. No. 7,590,861, which claims priority under 35 U.S.C. §119(e) to provisional patent application Ser. No. 60/401,399 filed on Aug. 6, 2002 entitled, "A Secure Enrollment Process for a Biometric Personal Identification Device," each of which is hereby incorporated by reference in its entirety.

This application is related to U.S. patent application Ser. No. 12/190,058, entitled "Methods for Secure Enrollment Of Personal Identity Credentials Into Electronic Devices," now U.S. Pat. No. 8,127,143, and U.S. patent application Ser. No. 12/190,061, entitled "Methods for Secure Backup of Personal Identity Credentials for Electronic Devices," now U.S. Pat. No. 7,788,501, and U.S. patent application Ser. No. 12/190,064, entitled "Methods for Secure Restoration of Personal Identity Credentials Into Electronic Devices," now U.S. Pat. No. 8,055,906, each filed on Aug. 12, 2008, and each of which is incorporated herein by reference its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to the field of information security, and more particularly to an enrollment process for devices capable of storing and releasing personal identity credentials based on authentication of a human fingerprint.

2. Necessity of the Invention

Devices and applications that use biometric authentication are increasing in popularity and frequency of use in applications where information security and privacy is critical. The success rates of devices that use biometrics as a form of authorization are dependent on the accuracy of the process by which information is associated with the biometric; for example, it must not be possible for John Doe to intercept Jane Doe's enrollment process and enroll Jane Doe's credentials into a device with his fingerprint. A generalized enrollment process includes capturing a biometric sample, ensuring the legitimacy of the sample and the individual providing the sample, storing the biometric sample in the appropriate location in the device, and enabling access rights to the enrolled individual. If this enrollment process is performed incorrectly or ineffectively then the process of biometric authentication and the implicit guarantee of enhanced security are easily defeated.

A variety of portable electronic devices with biometric authentication are available to consumers. These include Hewlett Packard's iPAQ Pocket PC h5450, 3M-AiT's VeriMe, Privaris' BPID™ Security Device, and Sony's FIU-900 Puppy®. Each device is capable of storing fingerprints and performing on-board matching. Several of these products are configurable to allow use of cryptographic keys after proof of biometric identification. As discussed in the following section, ownership of cryptographic keys is typically used as a form of remote identification when individuals are communicating digitally. It is imperative, then, that the fingerprint is definitively linked to an individual, so that the cryptographic keys cannot be misused.

Furthermore, because the enrollment process must necessarily be stringent, and likely time-consuming, it is desirable to have a simple method of archiving and restoring enrolled credentials and fingerprints. Clearly the method must be inherently secure, because the entire enrollment process could be overridden by a compromise of the backup process.

DESCRIPTION OF THE RELATED ART

Public Key Infrastructure

The public key infrastructure (PKI) and digital certificates are very common and, when used correctly, can be used to guarantee a 'cryptographic identity' of an individual. The most common form of the PKI uses the RSA algorithm, which is now freely available to the public.

To use the PKI, an individual—Alice—applies for a digital certificate from a trusted authority. After a substantive background investigatory process, the trusted authority decides that Alice is who she claims to be and decides to issue a digital certificate. The certificate includes a public key, one half of an asymmetric key pair, which is assigned only to Alice. She retains the other half of the key pair, the private key. Due to the fundamental principles of public key cryptography, anything encrypted by the Alice's private key can only be decrypted using her public key, and vice versa. Alice is free to distribute the digital certificate and the public key to whomever she wishes.

When another individual, Bob, wishes to send a message to Alice, he encrypts it with her public key. Alice receives the encrypted message and uses her private key to decrypt it. Because Alice is the unique owner of her public key, Bob knows that she possesses the unique and accompanying private key. Additionally, Bob sees that a trusted authority, which he knows performs substantive background checks, issued the digital certificate issued to Alice. He is assured that the only person who can read the message is truly Alice. This assures one-way security.

However, Alice cannot be sure that Bob sent her the message, because her public key is freely accessible. To combat this problem, Bob also requests and receives a digital certificate from a trusted authority. Bob writes his message and then creates a digital signature for the message. He first creates a hash of the message; this process creates a fixed-length string that is unique to the message but cannot be used to deduce the message. He then encrypts this hash using his private key and appends the encrypted hash to his message. The message and encrypted hash are now encrypted with Alice's public key, and transmitted to her.

Alice first decrypts the message with her private key. She can now read the message, as described above. However, she also has the encrypted hash, which she can use to verify that Bob sent the message. She uses Bob's public key to decrypt the digital signature and obtain the hash. Alice then hashes the received message herself, using the same hash algorithm as

Bob. If she obtains the same hash value as the one transmitted by Bob, she is assured that the message has not changed, and that he did actually send the message.

Enrollment Processes

3M-AiT's VeriMe stores a biometric template and a cryptographic private key for one user. When the user wishes to use the cryptographic private key, he or she must supply the correct biometric template. According to the VeriMe fact sheet, the private key is generated at the time of "secure registration" of the fingerprint. However, the fact sheet does not describe the secure registration or what it entails; it also does not discuss a secure backup and recovery process.

Biometric Associates (BAI) produces a fingerprint sensor that can be embedded into a smartcard. The smartcard can then be used to perform local biometric authentication, like the devices described above. According to BAI's website, the cards can enroll up to eight users with the use of a BAI Enrollment Station. The Enrollment Station provides external equipment necessary to instruct the smartcard to start enrolling fingerprints and personal credentials. However, the published information does not describe a secure cryptographic process for accomplishing this. It also does not describe secure backup and recovery processes.

BRIEF SUMMARY OF THE INVENTION

The invention disclosed herein describes processes for securely enrolling personal identity credentials into devices with means for personal identification. For example, a handheld computer with a biometric sensor may use enrolled fingerprints to identify a user when he requests access to stored information. The enrollment of the fingerprint must tie the user definitively to the fingerprint so that future authorizations are valid.

The invention described herein provides a process for enrollment wherein a manufacturer of a personal identification device records serial numbers or another unique identifier for each device that it produces, along with a self-generated public key for each device. An enrollment authority is recognized by the manufacturer or another suitable institution as capable of validating an individual before enrolling him into the device-maintains and operates the appropriate equipment for enrollment, and provides its approval of the enrollment.

The methods described herein are directed to post-manufacturing processes for the device, as well as the enrollment itself. Additionally, the invention describes methods for securely archiving enrolled personal identity credentials. This is to allow users to restore previously validated credentials into a new device without requiring a completely new enrollment. Correspondingly, the invention describes the restoration process, in which the stored credentials are securely downloaded into the new device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1: Post-manufacturing process

- 101 Provide manufacturer's public key to device
- 102 Generate key pair for device
- 103 Provide device' public key and unique ID to manufacturer
- 104 Create digital certificate for device
- 105 Provide digital certificate to device
- 106 Store device' public key and unique ID
- 107 Disable device

FIG. 2: Enrollment

- 201 Request permission from enrollment authority to enroll credentials into device
- 202 Validate the request
- 203 Present device' digital certificate
- 204 Verify that device is true owner of the certificate
- 205 Present enrollment authority's digital certificate
- 206 Verify that enrollment authority is true owner of the certificate
- 207 Create a session key
- 208 Complete enrollment, encrypting with the session key

FIG. 3: Backup

- 301 Create symmetric biometric encryption and decryption key
- 302 Encrypt the biometric with the symmetric biometric encryption and decryption key
- 303 Divide the symmetric biometric encryption and decryption key into two parts
- 304 Encrypt first part with a passphrase
- 305 Digitally sign second part with primary device' private key
- 306 Encrypt digital signature and second part of symmetric biometric encryption and decryption key with the controller's public key
- 307 Create symmetric personal identity credential encryption and decryption key
- 308 Digitally sign personal identity credential with primary device' private key
- 309 Encrypt credential with symmetric personal identity credential encryption and decryption key
- 310 Divide symmetric personal identity credential encryption and decryption key
- 311 Encrypt first part of symmetric personal identity credential encryption and decryption key with passphrase
- 312 Digitally sign second part of symmetric personal identity credential encryption and decryption key with primary device' private key
- 313 Encrypt digital signature and second part of symmetric personal identity credential encryption and decryption key with controller's public key
- 314 Store the encrypted biometric, encrypted credentials, and encrypted symmetric biometric encryption and decryption key and symmetric personal identity credential encryption and decryption key in an electronic storage repository
- 315 Provide user with a digital certificate containing the primary device' public key

FIG. 4: Restoration

- 401 Access the electronic storage repository
- 402 Obtain both parts of the symmetric biometric encryption and decryption key
- 403 Decrypt the first part with a passphrase
- 404 Decrypt the second part and the digital signature with the controller's private key
- 405 Verify the digital signature using the primary device' public key
- 406 Combine both parts of the symmetric biometric encryption and decryption key
- 407 Decrypt the biometric
- 408 Store the biometric in the secondary device
- 409 Obtain both parts of the symmetric personal identity credential encryption and decryption key
- 410 Decrypt the first part with a passphrase
- 411 Decrypt the second part and the digital signature with the controller's private key
- 412 Verify the digital signature using the primary device' public key

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413 Combine both parts of the symmetric personal identity credential encryption and decryption key

414 Decrypt the personal identity credential and the associated digital signature

415 Verify the digital signature using the primary device' public key

416 Store the personal identity credential in the secondary device

FIG. 1 is a flow chart illustrating the post-manufacturing process for a personal identification device.

FIG. 2 is a flow chart illustrating the process for enrolling personal identity credentials into the personal identification device.

FIG. 3 is a flow chart illustrating the backup process for securely storing personal identity credentials for future restoration.

FIG. 4 is a flow chart illustrating the restoration process.

DETAILED DESCRIPTION

The following detailed description is of the best presently contemplated modes of carrying out the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating general principles of embodiments of the invention.

The invention disclosed herein provides a process for securely enrolling individuals into devices with means for personal identification via use of biometric authentication (hereafter referred to as 'personal identification devices'). Because these devices are intended for use as trusted authentication devices, it is imperative that all of the information stored within the device be placed there in such a manner that it cannot be altered without proper authorization. There are two participants in the enrollment process, the manufacturer of the personal identification device and an enrollment authority.

The enrollment process includes identifying the device post-manufacturing and enrolling personal identity credentials and an associated biometric into the personal identification device. Furthermore, the invention also discloses methods for creating secure backup and recovery processes, such that an individual may securely store the enrolled information in an electronic storage repository, such as a hard drive. If his personal identification device fails he can use the recovery process to transfer the stored, enrolled information to a new device.

The two participants in the enrollment process must be definitely and separately identified for proper enrollment. The first participant in the enrollment system is the manufacturer of the personal identification device. The manufacturer is responsible for maintaining a database of unique identifiers, such as serial numbers, for all of the devices that it produces. This enables it later to determine if it manufactured a particular device. The second party is an enrollment authority, which is responsible for investigating, authorizing and performing individuals' requests for enrollment into a personal identification device. This participant may be a Department of Motor Vehicles, a building security officer, or any other person or organization responsible for issuing personal identification devices.

Initial Enrollment

This enrollment system uses the PKI described above. Each manufacturer and enrollment authority is provided with at least one asymmetric key pair that can be used for identification and encryption. The key pairs may be self generated, but the public key for each must be placed in a digital certificate signed by a trusted authority. Additionally, the manufac-

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turer may wish to sign digital certificates owned by the enrollment authority as means for guaranteeing its approval of the enrollment authority.

FIG. 1 demonstrates the post-manufacturing process that begins the enrollment process for a personal identification device. Immediately following manufacturing, each personal identification device receives a public key possessed by its manufacturer (step 101). In the preferred embodiment this key is received as part of a digital certificate. The personal identification device can use this public key to verify the digital signature on messages transmitted from the manufacturer and accept them as legitimate instructions. This step requires that the manufacturing process be secure and tamper-resistant; receiving a key other than a trusted manufacturer's would directly compromise future security verifications.

The personal identification device now generates an asymmetric key pair for itself (step 102). The public key and the device's unique identifier are sent to the manufacturer (step 103). The manufacturer, or other legitimate certificate authority, generates a digital certificate for the device (step 104). This is now sent back to the device, and can be signed by the manufacturer as a token of its legitimacy (step 105). The manufacturer keeps a record of the device's public key and its unique identifier for future reference (step 106). At this point all functionality within the personal identification device is disabled, such that it is in a state waiting for future enrollment (step 107).

As seen in FIG. 2, upon receipt of a personal identification device, an individual requests enrollment rights from an enrollment authority (step 201). This may require that the individual be physically present in a specified location, or may be performed remotely. The enrollment authority may establish all rules pertaining to the applicant verification process. The security and authenticity of the personal identification device is only as good as that of the verification process, so it is anticipated that these processes will be as stringent as required by the end application.

After approving the applicant, the enrollment authority receives the personal identification device's digital certificate (steps 202 and 203). The enrollment authority validates the digital certificate by prompting the device to encrypt a predetermined string with its private key (step 204). The enrollment authority now decrypts the encrypted string using the public key stored in the device's digital certificate, and verifies that the decrypted string matches the predetermined string. At this point the personal identification device will receive and verify the validity of the enrollment authority's digital certificate (steps 206 and 206). It performs the same prompt and verification process described above, and can also verify the manufacturer's signature on the certificate if one exists. After confirming the legitimacy of the enrollment authority, the personal identification device creates a session key and securely releases it to the enrollment authority (step 207). The personal identification device and the enrollment authority can now communicate freely using the session key (step 208). The biometric may be downloaded into the personal identification device along with the personal identity credentials, or may alternatively be sensed locally using the device and stored locally. The enrollment process, at this stage, is application-dependent and requires the establishment of requisite credentials, etc., which are not covered within the scope of this invention.

Restoration Processes

It may be necessary in some cases to provide a backup of at least one enrolled personal identity credential and biometric. The backup may be used in the event that the personal identification device fails, such that the individual may re-enroll a

new personal identification device without undergoing the entire process described above; these devices are referred to as the 'primary personal identification device' and the 'secondary personal identification device,' respectively.

Backup

There are two distinct parts of the restoration process. The first part describes a method for archiving the enrolled personal identity credential, which allows an enrolled individual to securely store his personal identity credential and biometric to a user-accessible computer disk or other electronic storage repository. This data is only accessible with permission from a device manufacturer, an enrollment authority, or a recovery authority, as specified by the implementer of the system. In the primary embodiment, this system controller will be the manufacturer of the primary personal identification device. The second part of the restoration process describes a method for restoring the stored data to the secondary personal identification device.

As seen in FIG. 3, the primary personal identification device generates a symmetric biometric encryption and decryption key (step 301). This key is used for encrypting a digital representation of the enrolled biometric (step 302), which can be used to unlock the archived personal identity credential(s). After encryption of the biometric, the symmetric biometric encryption and decryption key is divided into two unique and distinct parts (step 303); the scheme of separation may be selected at the discretion of the system implementer. The first part of the symmetric biometric encryption and decryption key is encrypted with a user-selected passphrase (step 304). The second part of the symmetric biometric encryption and decryption key is signed by a private key possessed by the primary personal identification device (step 305), and is then encrypted with a public key owned by the system controller (step 306). As described above, in this embodiment the system controller is the primary personal identification device manufacturer. Using the manufacturer's public key forces an individual to request restoration privileges from the manufacturer during restoration, because the individual needs the manufacturer to decrypt the data with its private key. This is discussed in further detail below.

The primary personal identification device then generates a symmetric personal identity credential encryption and decryption key (step 307), which is used for encrypting at least one enrolled personal identity credential. The primary personal identification device first digitally signs the personal identity credential, using a private key (step 308), and then encrypts the personal identity credential and associated digital signature (step 309). Similarly to the scheme described above, the symmetric personal identity credential encryption and decryption key is divided (step 310) into two unique and distinct parts. The first part is encrypted with a user-selected passphrase (step 311), which may or may not be the same passphrase as used above. The second part is again signed by the device's private key (step 312) and encrypted with the manufacturer's public key (step 313).

All of the encrypted and/or signed data—the biometric, the symmetric biometric encryption and decryption key, the personal identity credential, and the symmetric personal identity credential encryption and decryption key—are now stored in an electronic storage repository (step 314). In typical embodiments the electronic storage repository could be a computer hard drive, floppy disk, or network drive. The primary personal identification device releases its digital certificate to the individual for future use of its public key (step 315).

Restoration

As seen in FIG. 4, when an individual receives a secondary personal identification device, and wishes to restore data from

a primary personal identification device, he must access the electronic storage repository (step 401). The individual must first acquire the two encrypted and/or signed parts of the symmetric biometric encryption and decryption key (step 402). The secondary personal identification device decrypts the first part of the symmetric biometric encryption and decryption key with the user's passphrase (step 403). It then requests the system controller, the manufacturer of the primary personal identification device, to decrypt the second part of the symmetric biometric encryption and decryption key and the associated digital signature using its (the manufacturer's) private key (step 404). Once the data has been decrypted, the secondary personal identification device verifies the digital signature using a public key possessed by the primary personal identification device (step 405). The two parts of the symmetric biometric encryption and decryption key are now combined appropriately (step 406), and can be used to decrypt the biometric (step 407). The biometric is now stored in an appropriate location within the secondary personal identification device (step 408).

The individual now obtains the two encrypted and/or signed parts of the symmetric personal identity credential encryption and decryption key (step 409). Similarly to the process described above, the secondary personal identification device decrypts the first part of the symmetric personal identity credential encryption and decryption key using a user-selected passphrase (step 410). It now requests the system controller, the manufacturer of the primary personal identification device, to decrypt the second part of the symmetric personal identity credential encryption and decryption key and the accompanying digital signature using its private key (step 411). Again, the secondary personal identification device verifies the digital signature using a public key possessed by the primary personal identification device (step 412). The two parts of the key are reconstructed to form one key (step 413). The key is now used to decrypt the personal identity credential and the associated digital signature (step 414), and the signature is verified using a public key owned by the primary personal identification device (step 415). The decrypted personal identity credential can now be stored appropriately within the secondary personal identification device (step 416).

While the description above refers to particular embodiments of the present invention, it will be understood that many modifications may be made without departing from the spirit thereof. The accompanying claims are intended to cover such modifications as would fall within the true scope and spirit of the present invention.

We claim:

1. A method, comprising:

receiving at a personal identification device a public key before biometric data associated with enrollment is received;

sending an identifier from the personal identification device to a party based on the public key before biometric data associated with enrollment is received, the identifier being uniquely associated with the personal identification device;

receiving at the personal identification device a digital certificate from the party based on the identifier before biometric data associated with enrollment is received; and

disabling functionality within the personal identification device except that the personal identification device is in a wait state associated with future enrollment.

2. The method of claim 1, further comprising sending the public key from the personal identification device to the party after the receiving the public key.

3. The method of claim 1, wherein the receiving the digital certificate from the party is based on the public key and the identifier.

4. The method of claim 1, wherein the identifier is associated with an asymmetric key pair including a personal identification device public key and a personal identification device private key.

5. The method of claim 1, further comprising producing the identifier at the personal identification device.

6. The method of claim 1, further comprising receiving at the personal identification device the identifier from the party.

7. The method of claim 1, wherein the digital certificate includes the public key.

8. The method of claim 1, wherein the party is a manufacturer of the personal identification device and separate from an enrollment party authorized to enable enrollment of the biometric data at the personal identification device.

9. The method of claim 1, wherein the party is a first party, the personal identification device being configured to enroll the biometric data from a second party different from the first party after the receiving at the personal identification device the digital certificate.

10. The method of claim 1, wherein the digital certificate includes data associated with the personal identification device.

11. A method, comprising:

sending a public key to a personal identification device;

receiving an identifier from the personal identification device, the identifier being uniquely associated with the personal identification device;

producing a digital certificate based on the identifier and before enrollment of biometric data; and

sending the digital certificate to the personal identification device such that functionality of the personal identification device is disabled except that the personal identification device is configured to send the digital certificate to an enrollment party during future enrollment.

12. The method of claim 11, wherein the producing of the digital certificate is based, at least in part, on the public key.

13. The method of claim 11, wherein the receiving and the producing is performed by a first party, the method further comprising:

receiving at the first party a digital certificate uniquely associated with a second party different from the first party;

adding a public key of the first party to the digital certificate associated with the second party; and

sending the digital certificate associated with the second party from the first party to the second party.

14. The method of claim 11, wherein the digital certificate includes the public key.

15. The method of claim 11, further comprising producing at the party an asymmetric key pair uniquely associated with the party.

16. The method of claim 11, wherein the public key is associated with a manufacturer of the personal identification device and separate from the enrollment party authorized to enable enrollment of the biometric data at the personal identification device.

17. The method of claim 11, wherein the personal identification device is configured to enroll biometric data from the enrollment party after the sending the digital certificate.

18. The method of claim 11, wherein the producing the digital certificate is based on data associated with the personal identification device.

19. A method, comprising:

receiving an encryption identifier at a personal identification device from a party during pre-enrollment;

receiving a digital signature at the personal identification device from the party during pre-enrollment;

the encryption identifier and the digital signature collectively configured to enable verification of the party by the personal identification device; and

disabling functionality within the personal identification device except for functionality associated with future enrollment.

20. The method of claim 19, wherein:

the encryption identifier is a public key; and

the receiving the digital signature including receiving a digital certificate including the digital signature.

21. A non-transitory computer-readable medium programmed with executable instructions that, when executed by a processing system, perform a method comprising:

receiving at a personal identification device a public key before biometric data associated with enrollment is received;

sending an identifier from the personal identification device to a party based on the public key before biometric data associated with enrollment is received, the identifier being uniquely associated with the personal identification device;

receiving at the personal identification device a digital certificate from the party based on the identifier before biometric data associated with enrollment is received; and

disabling functionality within the personal identification device except that the personal identification device is in a wait state associated with future enrollment.

22. The medium of claim 21, further comprising sending the public key from the personal identification device to the party after the receiving the public key.

23. The medium of claim 21, wherein the receiving the digital certificate from the party is based on the public key and the identifier.

24. The medium of claim 21, wherein the identifier is associated with an asymmetric key pair including a personal identification device public key and a personal identification device private key.

25. The medium of claim 21, further comprising producing the identifier at the personal identification device.

26. The medium of claim 21, further comprising receiving at the personal identification device the identifier from the party.

27. The medium of claim 21, wherein the digital certificate includes the public key.

28. The medium of claim 21, wherein the party is a manufacturer of the personal identification device and separate from an enrollment party authorized to enable enrollment of the biometric data at the personal identification device.

29. The medium of claim 21, wherein the party is a first party, the personal identification device being configured to enroll the biometric data from a second party different from the first party after the receiving at the personal identification device the digital certificate.

30. The medium of claim 21, wherein the digital certificate includes data associated with the personal identification device.

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31. A non-transitory computer-readable medium programmed with executable instructions that, when executed by a processing system, perform a method comprising:

5 sending a public key to a personal identification device;
receiving an identifier from the personal identification device, the identifier being uniquely associated with the personal identification device;

producing a digital certificate based on the identifier and before enrollment of biometric data; and

10 sending the digital certificate to the personal identification device such that functionality of the personal identification device is disabled except that the personal identification device is configured to send the digital certificate to an enrollment party during future enrollment.

32. The medium of claim **31**, wherein the producing of the digital certificate is based, at least in part, on the public key.

33. The medium of claim **31**, wherein the receiving and the producing is performed by a first party, the method further comprising:

15 receiving at the first party a digital certificate uniquely associated with a second party different from the first party;

adding a public key of the first party to the digital certificate associated with the second party; and

20 sending the digital certificate associated with the second party from the first party to the second party.

34. The medium of claim **31**, wherein the digital certificate includes the public key.

35. The medium of claim **31**, further comprising producing at the party an asymmetric key pair uniquely associated with the party.

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36. The medium of claim **31**, wherein the public key is associated with a manufacturer of the personal identification device and separate from the enrollment party authorized to enable enrollment of the biometric data at the personal identification device.

37. The medium of claim **31**, wherein the personal identification device is configured to enroll biometric data from the enrollment party after the sending the digital certificate.

10 **38.** The medium of claim **31**, wherein the producing the digital certificate is based on data associated with the personal identification device.

39. A non-transitory computer-readable medium programmed with executable instructions that, when executed by a processing system, perform a method comprising:

15 receiving an encryption identifier at a personal identification device from a party during pre-enrollment;

receiving a digital signature at the personal identification device from the party during pre-enrollment;

20 the encryption identifier and the digital signature collectively configured to enable verification of the party by the personal identification device; and

disabling functionality within the personal identification device except for functionality associated with future enrollment.

25 **40.** The medium of claim **39**, wherein:

the encryption identifier is a public key; and

the receiving the digital signature including receiving a digital certificate including the digital signature.

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