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Ramachandran et al.

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(45) **Date of Patent:** **Aug. 12, 2025**

(54) **SYSTEMS AND METHODS FOR MANAGING CRYPTOCURRENCY**

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Related U.S. Application Data

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(51) **Int. Cl.**

G06Q 20/38	(2012.01)
G06Q 20/22	(2012.01)

(Continued)

(52) **U.S. Cl.**
CPC ***G06Q 20/3825*** (2013.01); ***G06Q 20/223*** (2013.01); ***G06Q 20/322*** (2013.01);
(Continued)

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

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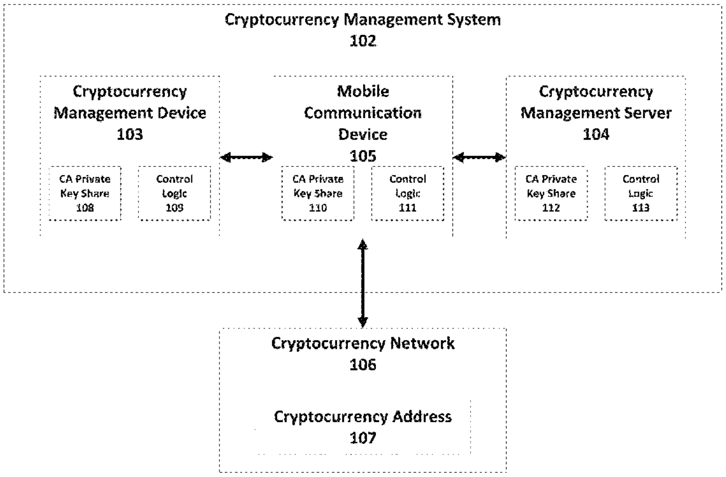
(57) **ABSTRACT**

A system for locally authenticating a transaction of digital financial assets, such as cryptocurrency. A first device may locally store financial assets in non- volatile memory of the first device. The first device may use the locally-stored financial assets to conduct a local transaction with a second device. The first device may generate a transaction settlement data token and exchange the token with the second device, wherein the transaction settlement data token includes information specific to the local transaction, a value associated with the local transaction, and encrypted personal information associated with the first device. After receiving a confirmation of transmission from the second device, the

(Continued)



value associated with the local transaction may be debited from the locally-stored financial assets.

18 Claims, 21 Drawing Sheets

(51) **Int. Cl.**
G06Q 20/32 (2012.01)
G06Q 20/40 (2012.01)

(52) **U.S. Cl.**
CPC ***G06Q 20/3278*** (2013.01); ***G06Q 20/3829*** (2013.01); ***G06Q 20/383*** (2013.01); ***G06Q 20/4014*** (2013.01); ***G06Q 20/40145*** (2013.01); *G06Q 2220/00* (2013.01)

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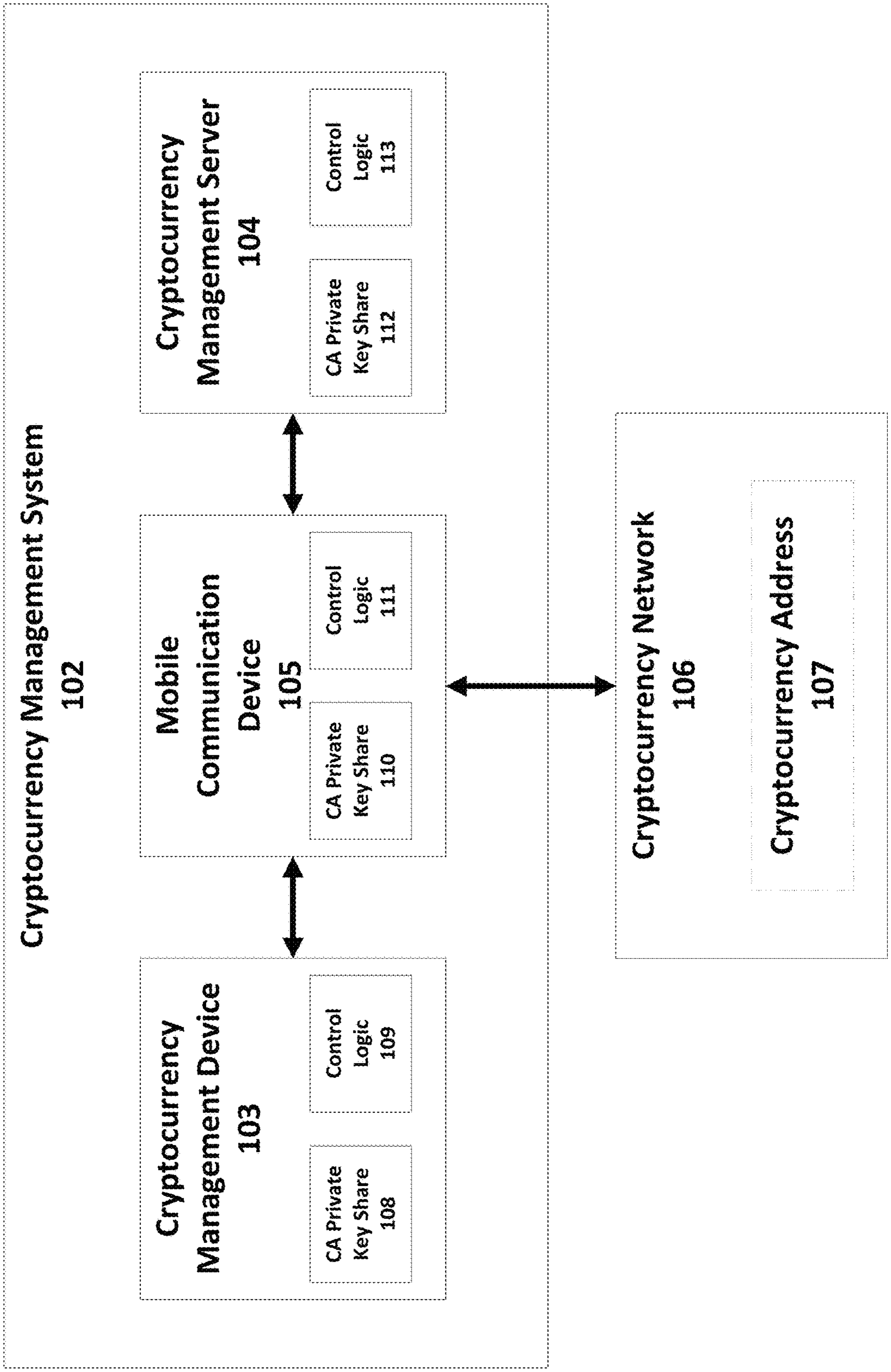
Cryptocurrency Management System
102
Cryptocurrency Management Device
103
CA Private Key Share
108
Control Logic
109
Mobile Communication Device
105
CA Private Key Share
110
Control Logic
111
Cryptocurrency Management Server
104
CA Private Key Share
112
Control Logic
113
Cryptocurrency Network
106
Cryptocurrency Address
107

FIG. 1

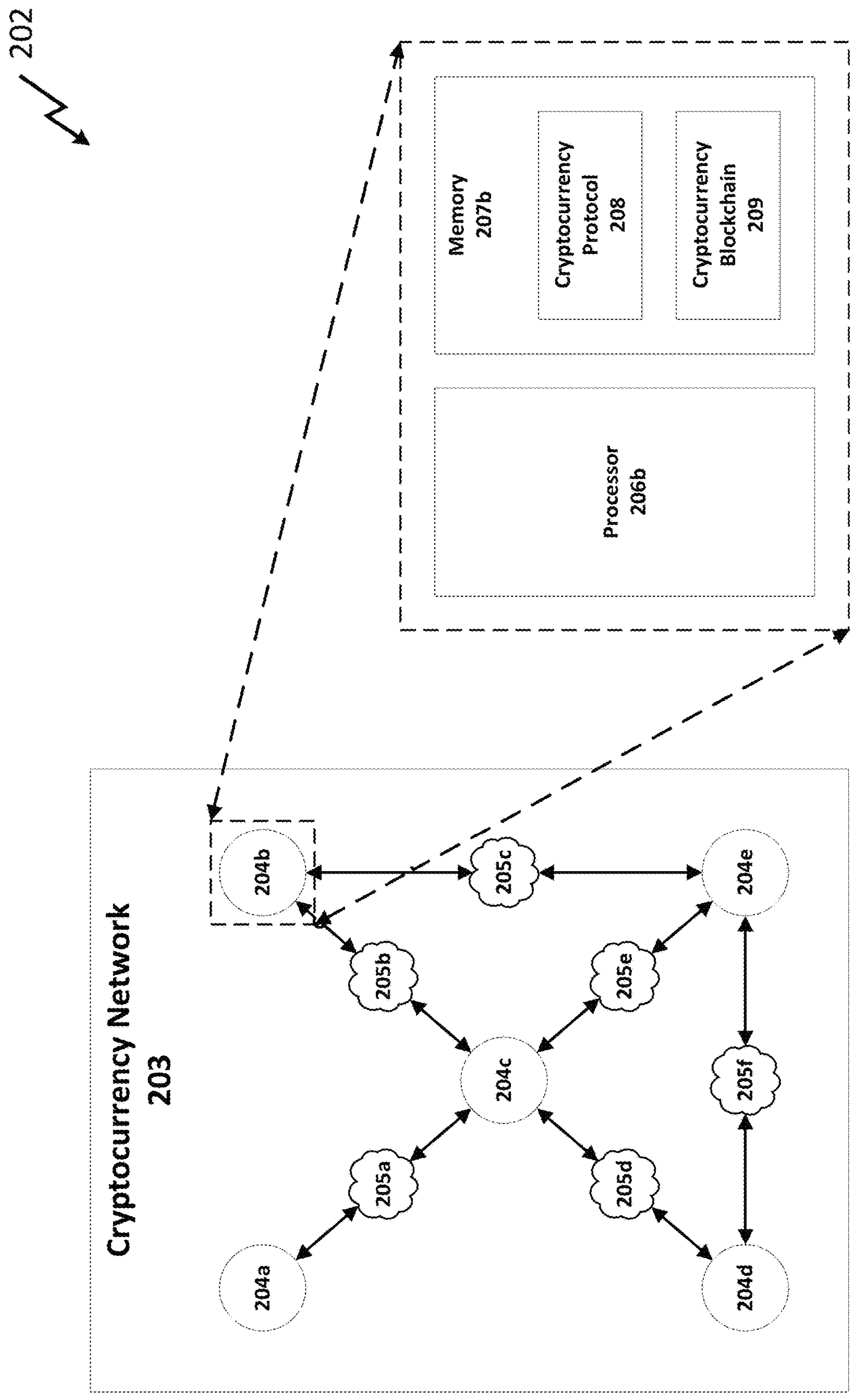
202
Cryptocurrency Network
203
204a
204b
204c
204d
204e
205a
205b
205c
205d
205e
205f
Processor
206b
Memory
207b
Cryptocurrency
Protocol
208
Cryptocurrency
Blockchain
209

FIG. 2

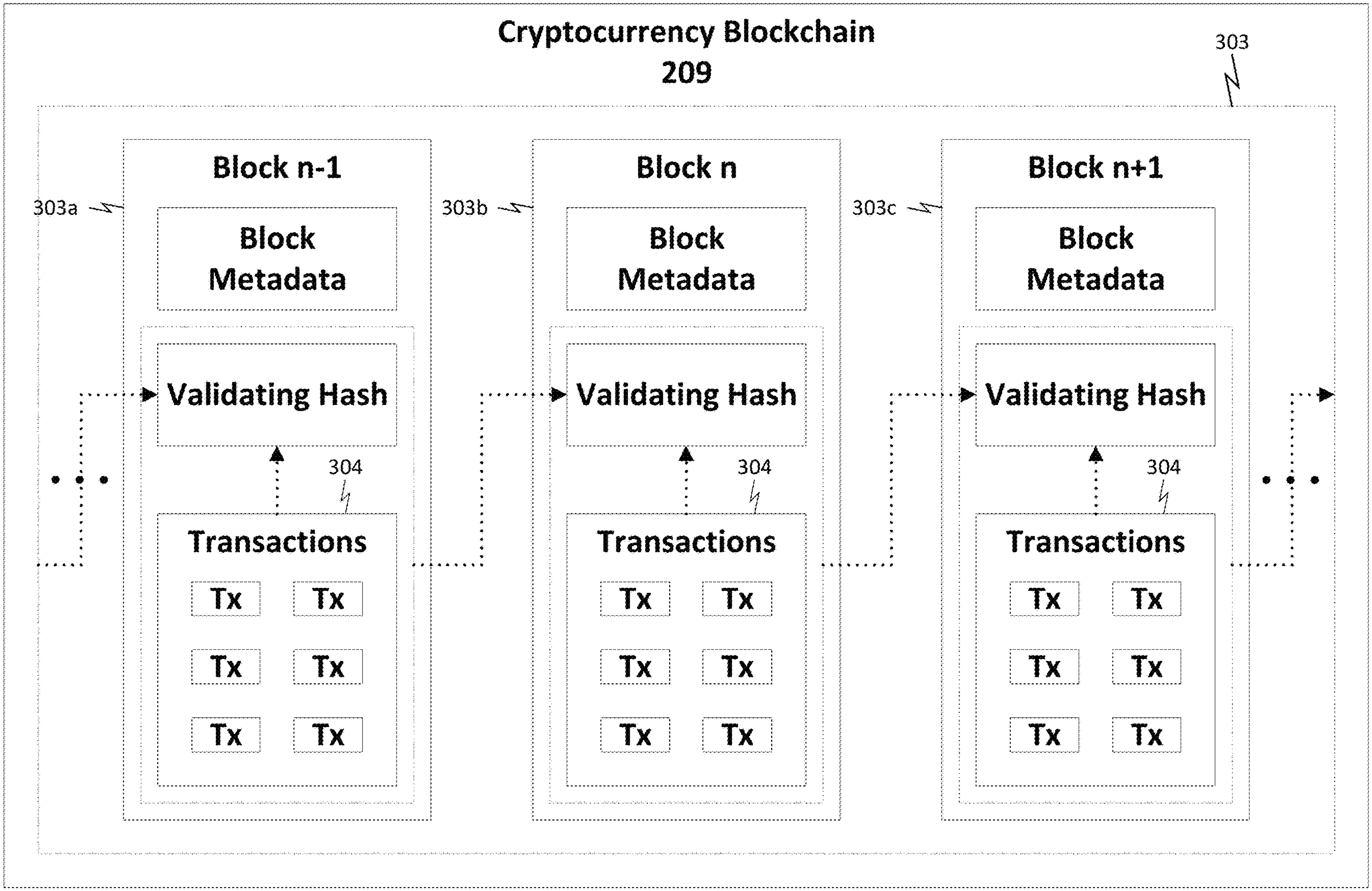
Cryptocurrency Blockchain
209
303
303a
303b
303c
Block n-1
Block n
Block n+1
Block Metadata
Block Metadata
Block Metadata
Validating Hash
Validating Hash
Validating Hash
304
304
304
Transactions
Tx Tx Tx Tx Tx Tx
Transactions
Tx Tx Tx Tx Tx Tx
Transactions
Tx Tx Tx Tx Tx Tx

FIG. 3

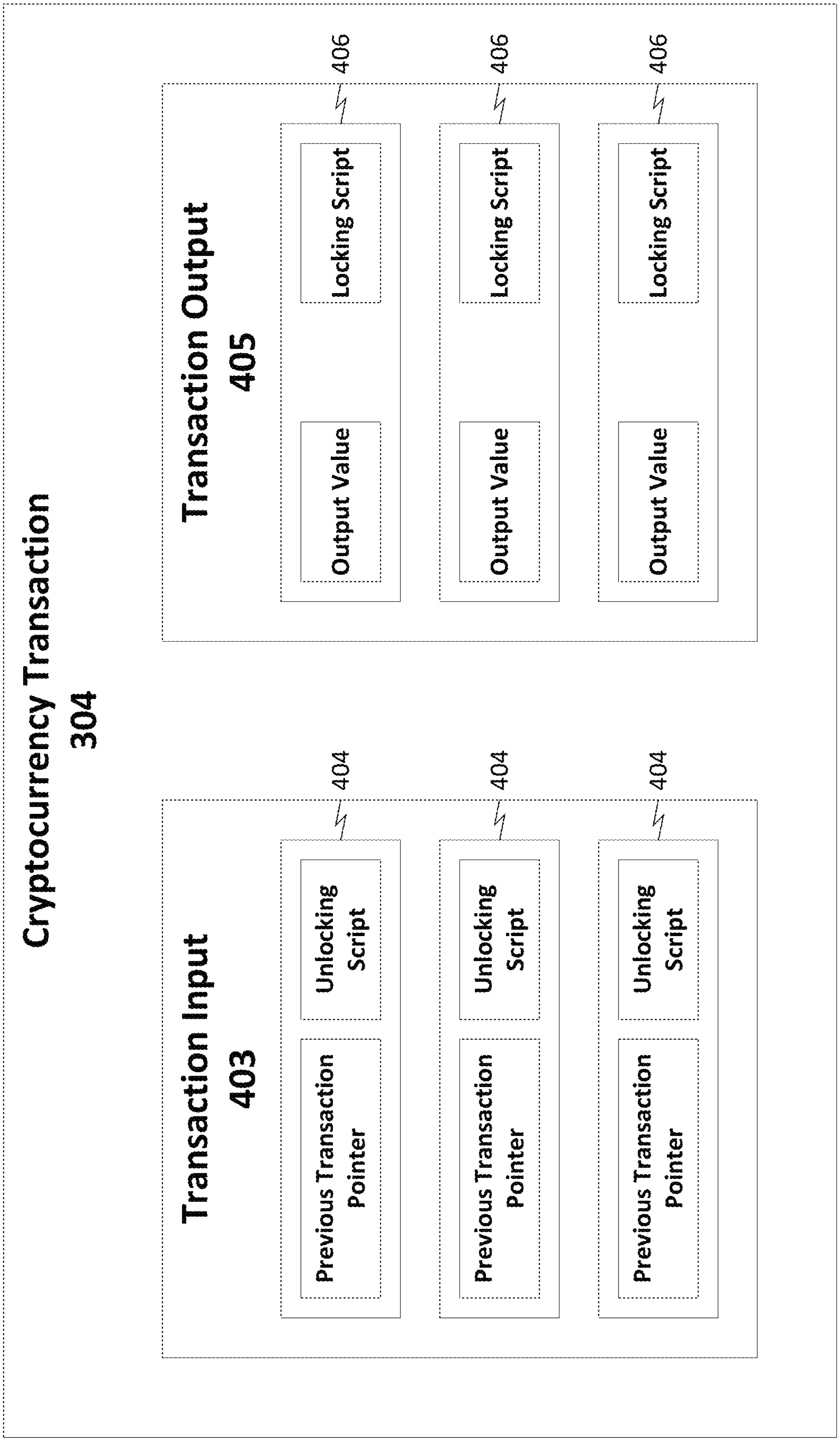
Cryptocurrency Transaction
304
Transaction Input
403
Previous Transaction Pointer
Unlocking Script
404
Previous Transaction Pointer
Unlocking Script
404
Previous Transaction Pointer
Unlocking Script
404
Transaction Output
405
Output Value
Locking Script
406
Output Value
Locking Script
406
Output Value
Locking Script
406

FIG. 4

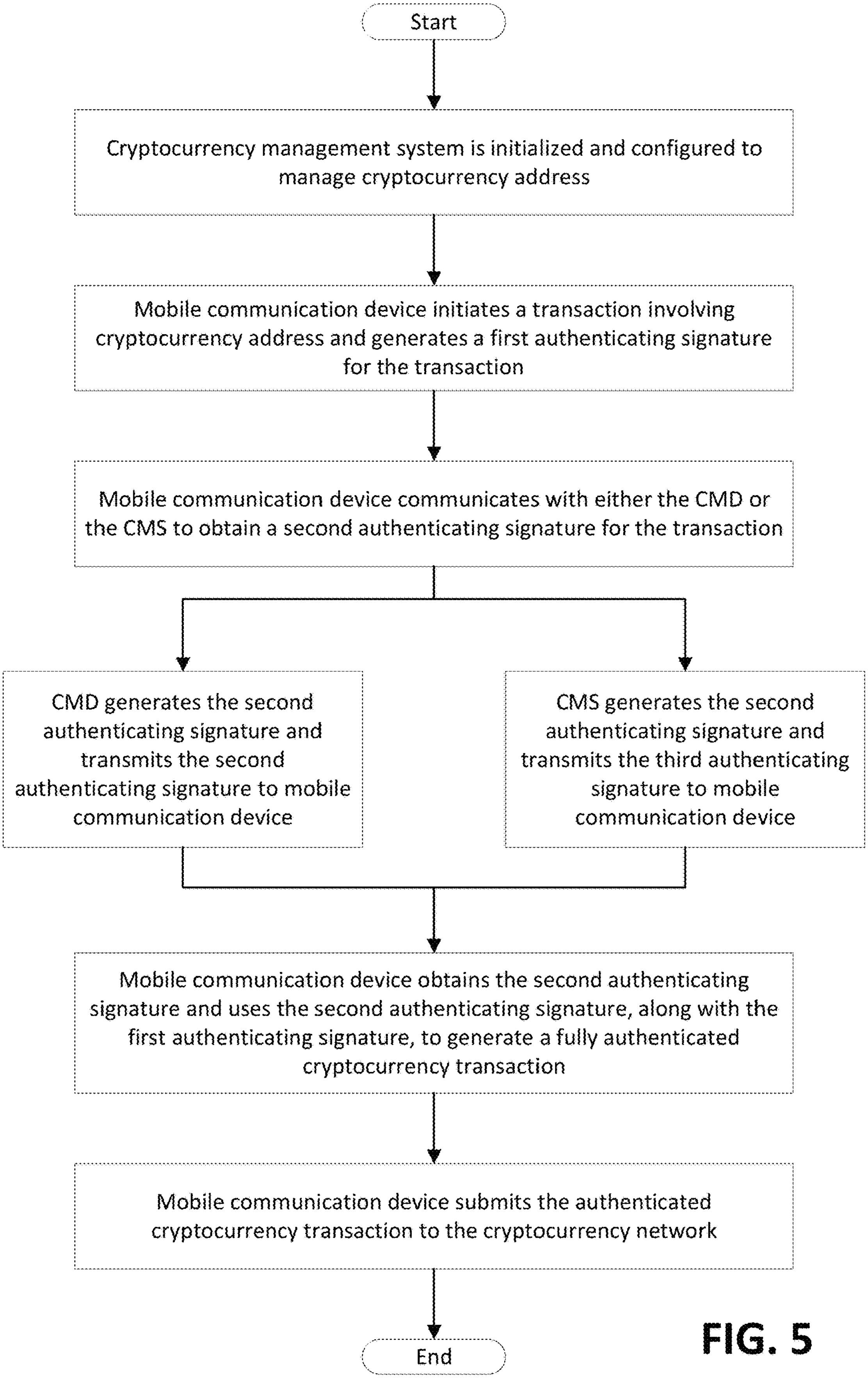
Start
Cryptocurrency management system is initialized and configured to manage cryptocurrency address
Mobile communication device initiates a transaction involving cryptocurrency address and generates a first authenticating signature for the transaction
Mobile communication device communicates with either the CMD or the CMS to obtain a second authenticating signature for the transaction
CMD generates the second authenticating signature and transmits the second authenticating signature to mobile communication device
CMS generates the second authenticating signature and transmits the third authenticating signature to mobile communication device
Mobile communication device obtains the second authenticating signature and uses the second authenticating signature, along with the first authenticating signature, to generate a fully authenticated cryptocurrency transaction
Mobile communication device submits the authenticated cryptocurrency transaction to the cryptocurrency network
End

FIG. 5

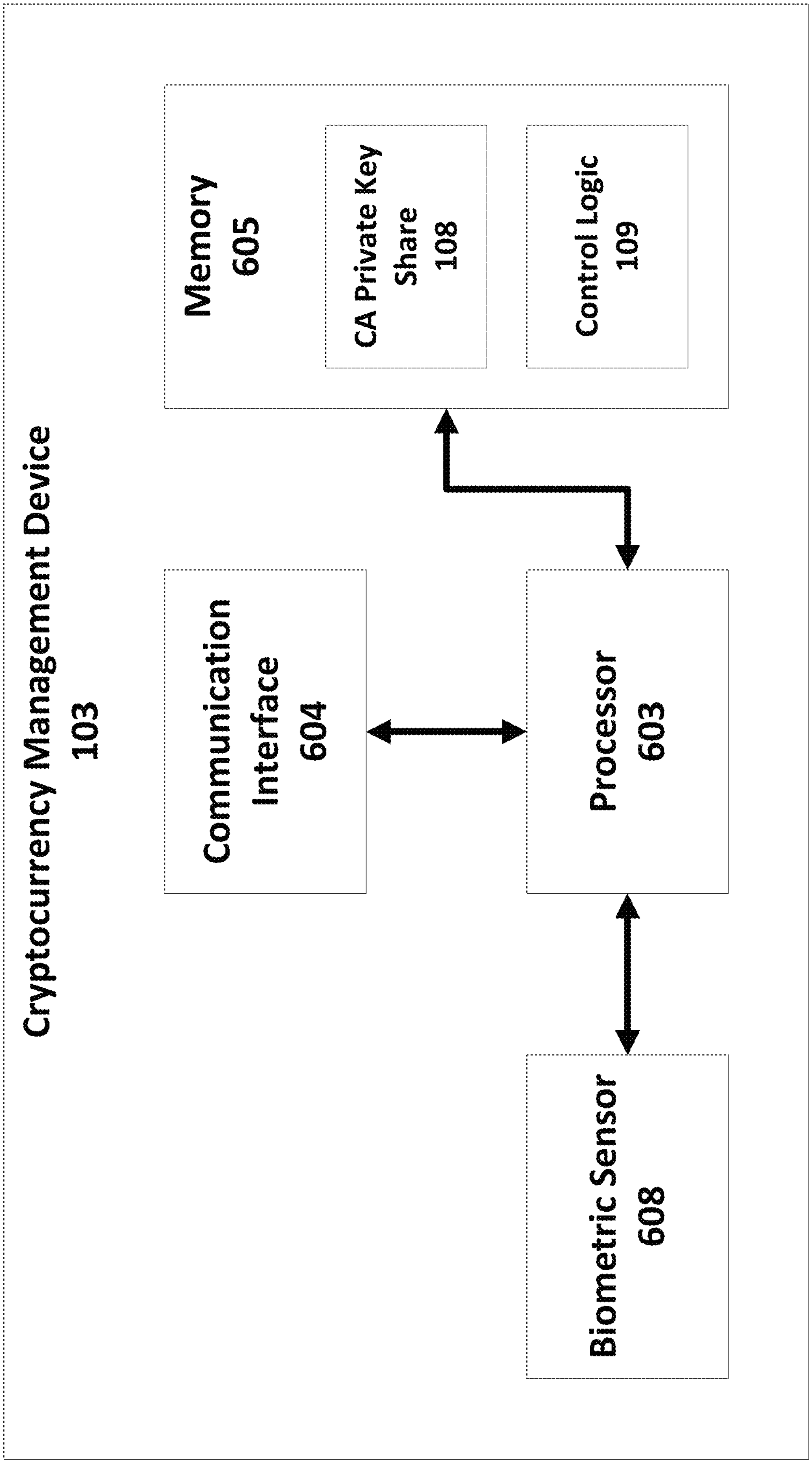
Cryptocurrency Management Device
103
Memory
605
CA Private Key
Share
108
Control Logic
109
Communication
Interface
604
Processor
603
Biometric Sensor
608

FIG. 6

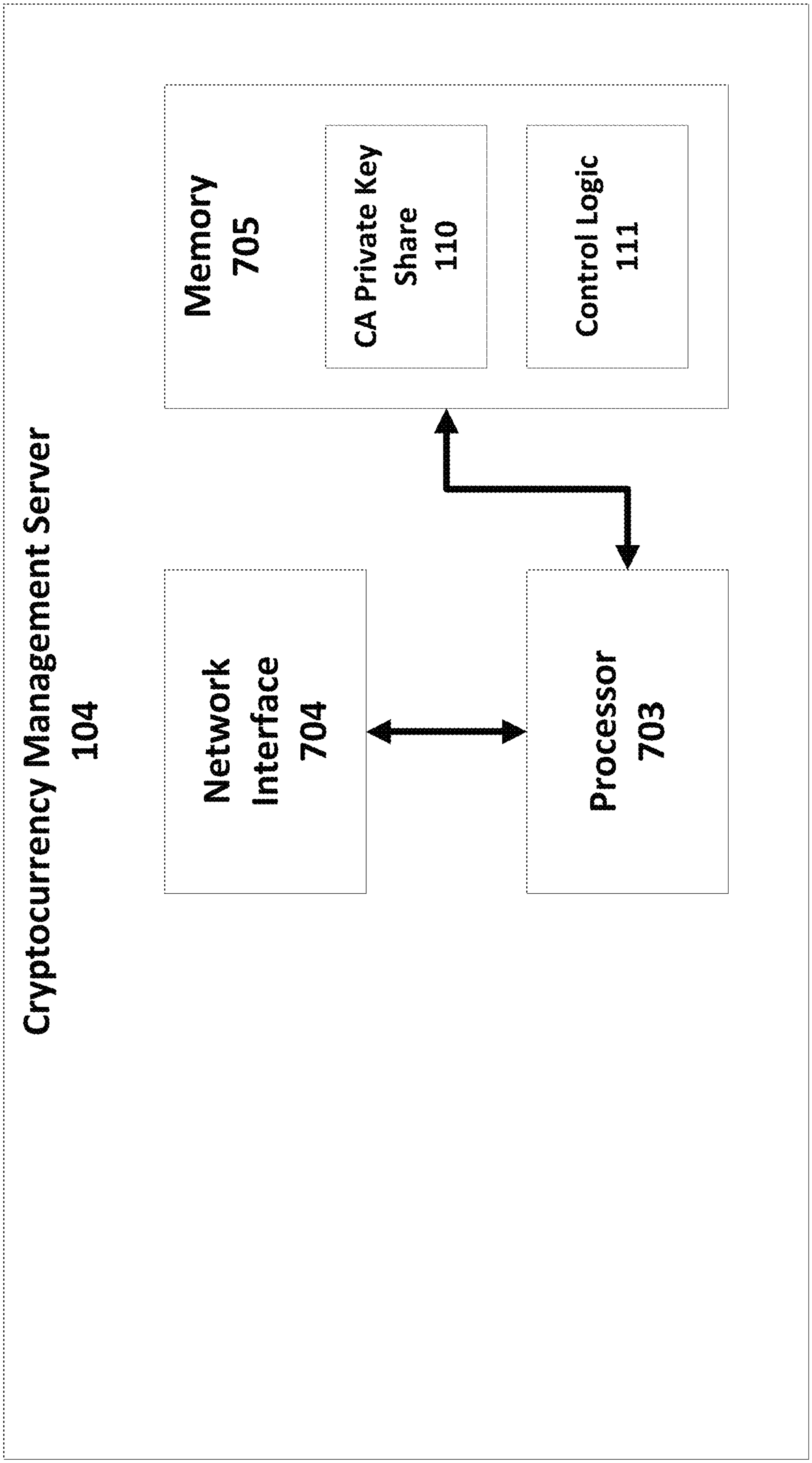
Cryptocurrency Management Server
104
Network
Interface
704
Processor
703
Memory
705
CA Private Key
Share
110
Control Logic
111

FIG. 7

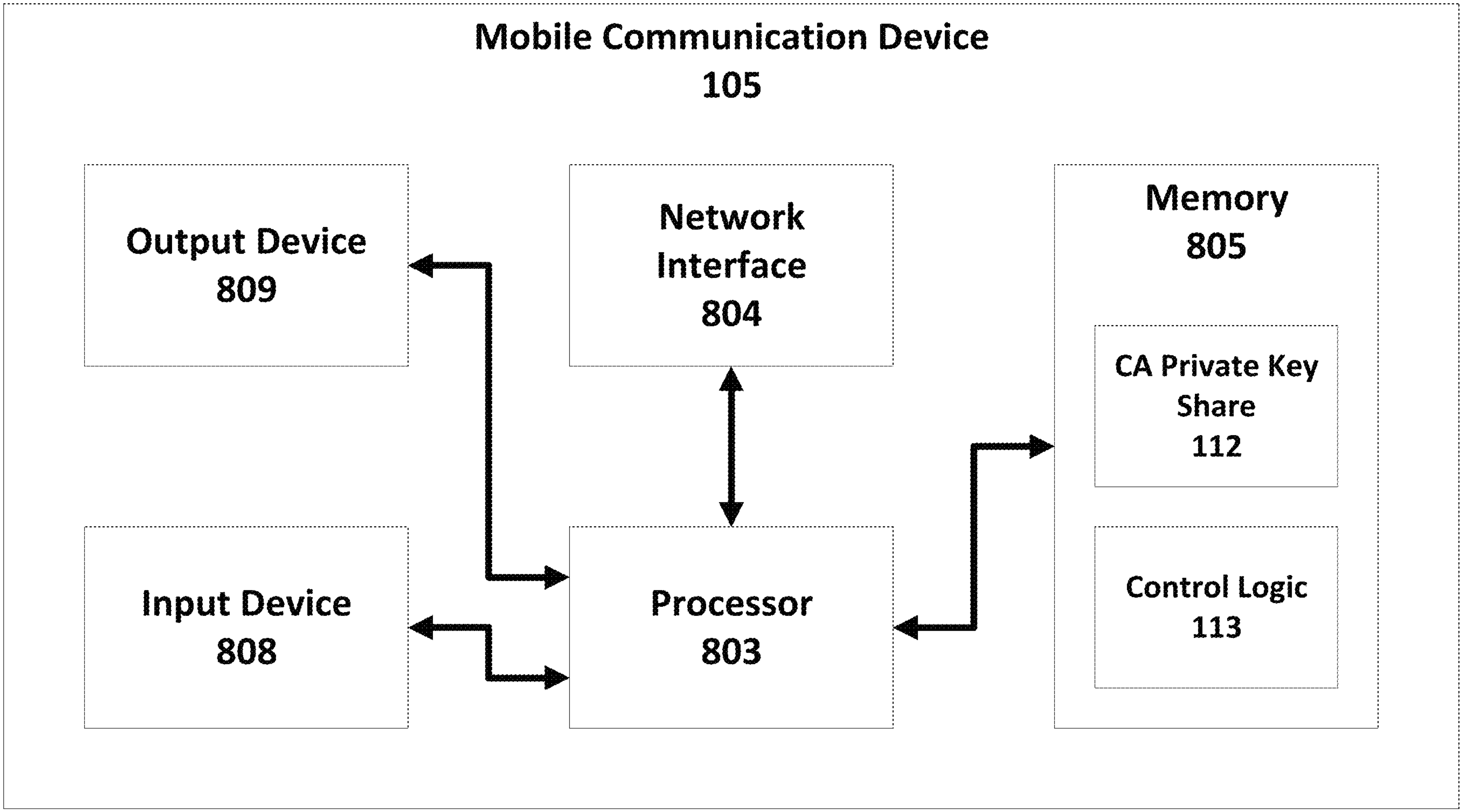
Mobile Communication Device
105
Output Device
809
Network
Interface
804
Memory
805
CA Private Key
Share
112
Control Logic
113
Input Device
808
Processor
803

FIG. 8

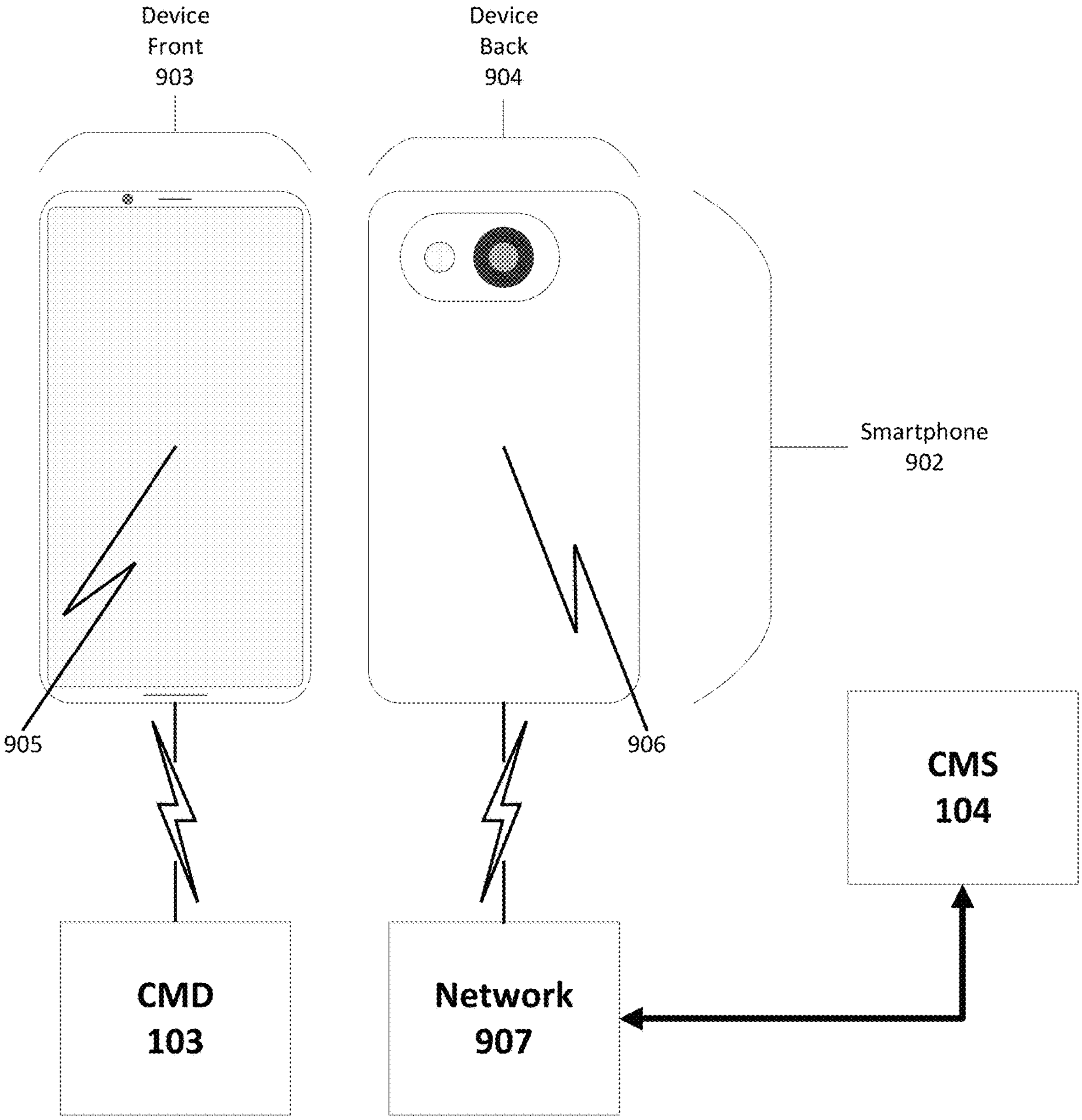
Device
Front
903
Device
Back
904
Smartphone
902
905
906
CMS
104
CMD
103
Network
907

FIG. 9

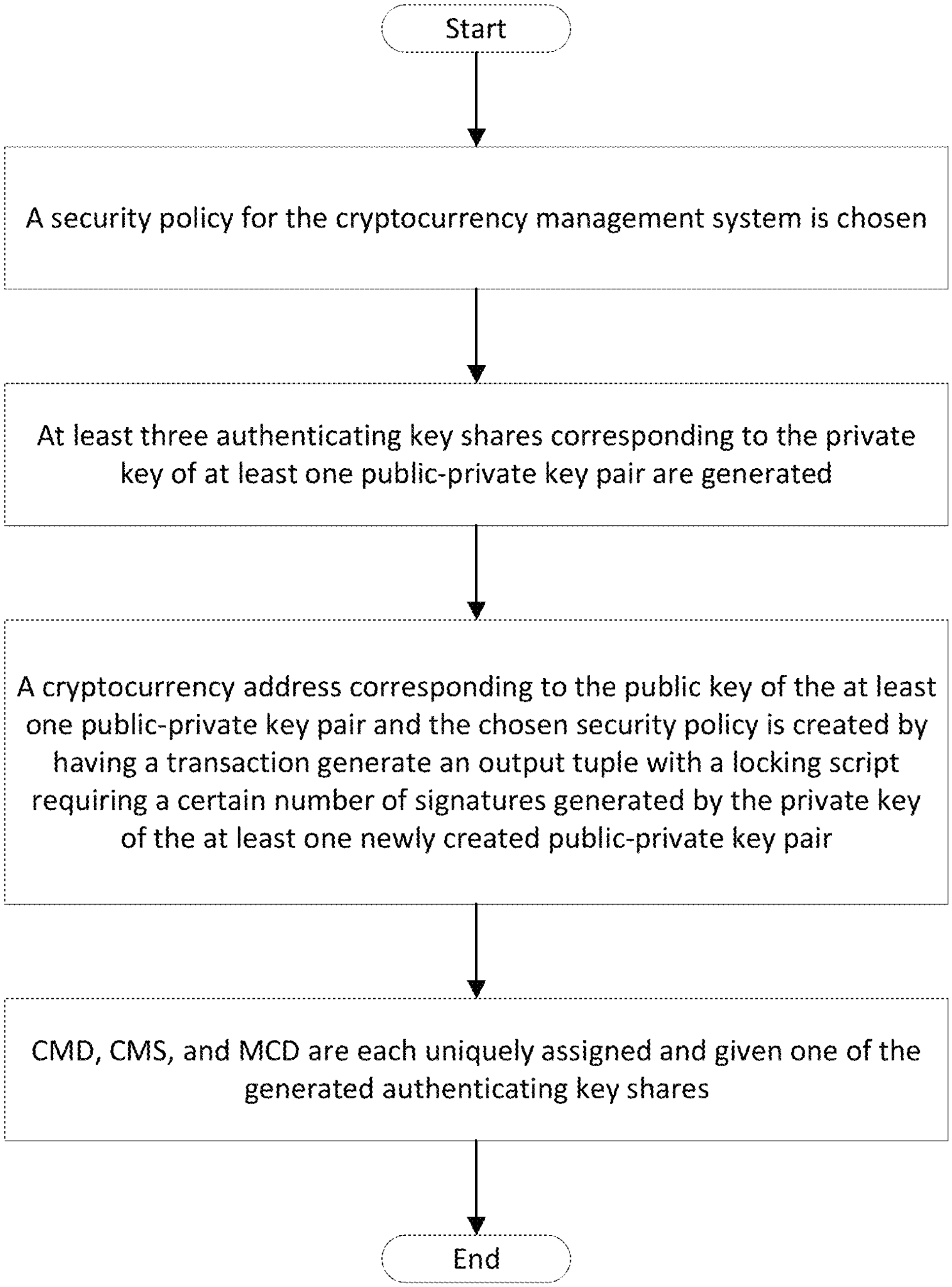
Start
A security policy for the cryptocurrency management system is chosen
At least three authenticating key shares corresponding to the private key of at least one public-private key pair are generated
A cryptocurrency address corresponding to the public key of the at least one public-private key pair and the chosen security policy is created by having a transaction generate an output tuple with a locking script requiring a certain number of signatures generated by the private key of the at least one newly created public-private key pair
CMD, CMS, and MCD are each uniquely assigned and given one of the generated authenticating key shares
End

FIG. 10

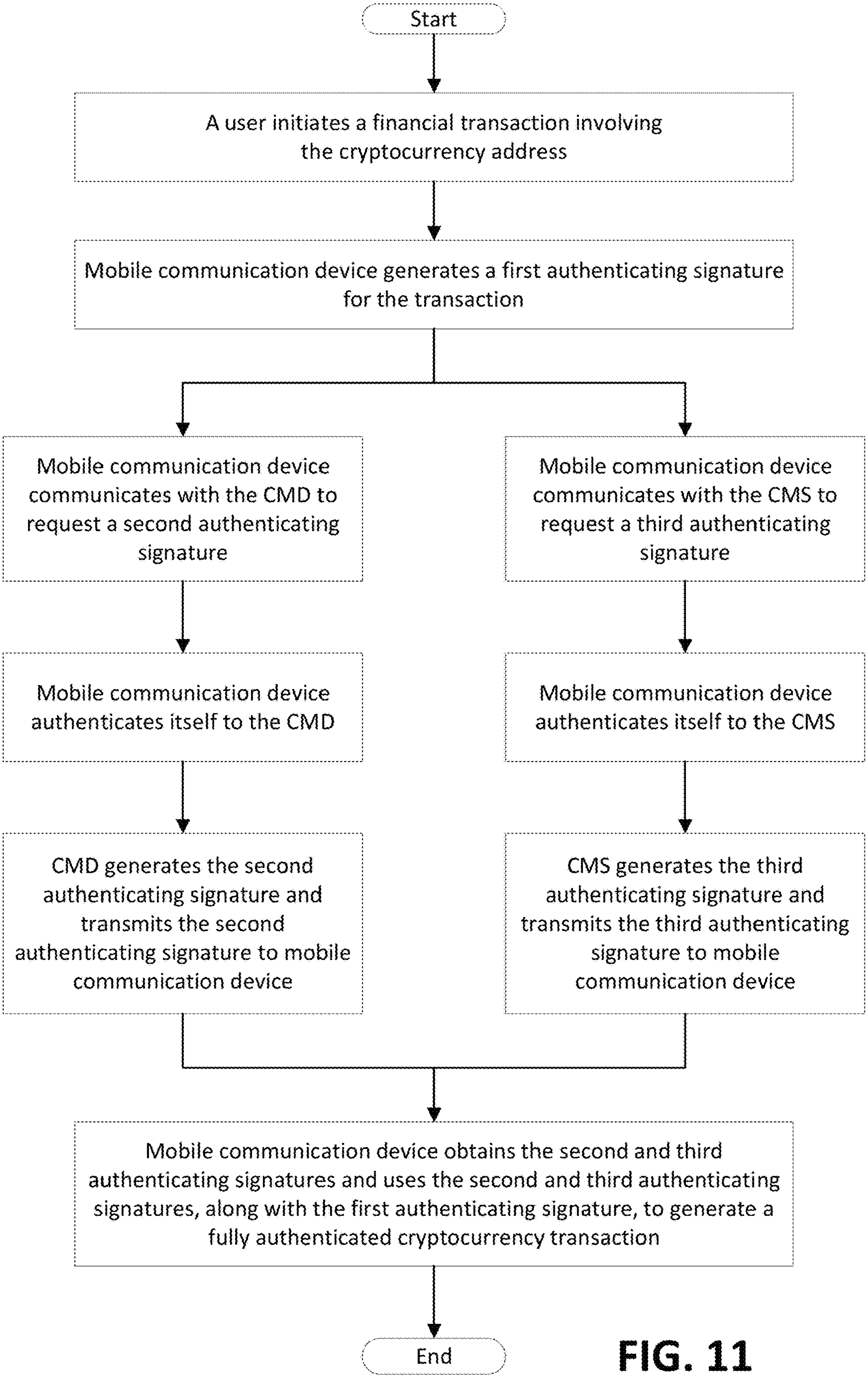
Start
A user initiates a financial transaction involving the cryptocurrency address
Mobile communication device generates a first authenticating signature for the transaction
Mobile communication device communicates with the CMD to request a second authenticating signature
Mobile communication device communicates with the CMS to request a third authenticating signature
Mobile communication device authenticates itself to the CMD
Mobile communication device authenticates itself to the CMS
CMD generates the second authenticating signature and transmits the second authenticating signature to mobile communication device
CMS generates the third authenticating signature and transmits the third authenticating signature to mobile communication device
Mobile communication device obtains the second and third authenticating signatures and uses the second and third authenticating signatures, along with the first authenticating signature, to generate a fully authenticated cryptocurrency transaction
End

FIG. 11

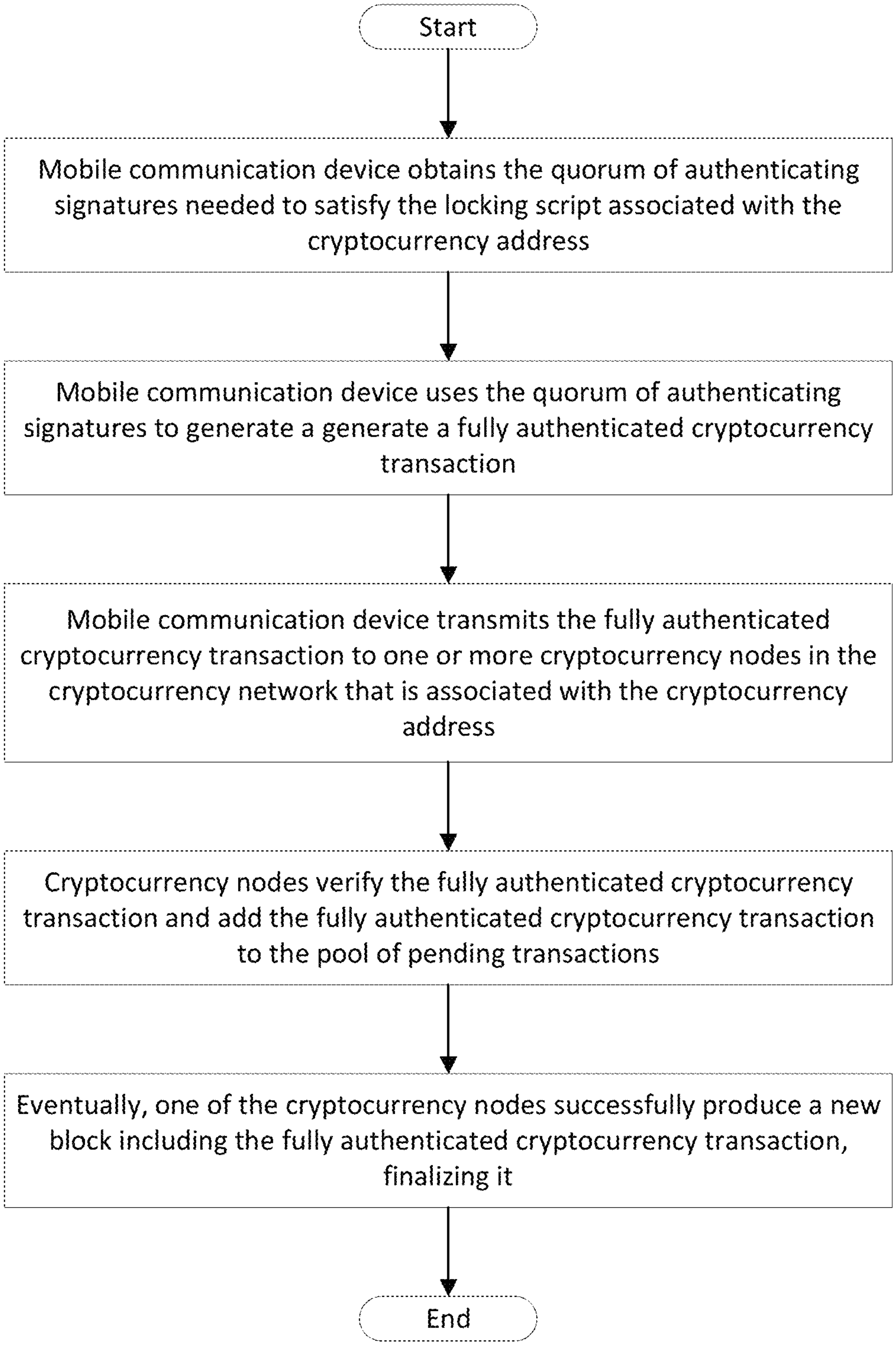
Start
Mobile communication device obtains the quorum of authenticating signatures needed to satisfy the locking script associated with the cryptocurrency address
Mobile communication device uses the quorum of authenticating signatures to generate a generate a fully authenticated cryptocurrency transaction
Mobile communication device transmits the fully authenticated cryptocurrency transaction to one or more cryptocurrency nodes in the cryptocurrency network that is associated with the cryptocurrency address
Cryptocurrency nodes verify the fully authenticated cryptocurrency transaction and add the fully authenticated cryptocurrency transaction to the pool of pending transactions
Eventually, one of the cryptocurrency nodes successfully produce a new block including the fully authenticated cryptocurrency transaction, finalizing it
End

FIG. 12

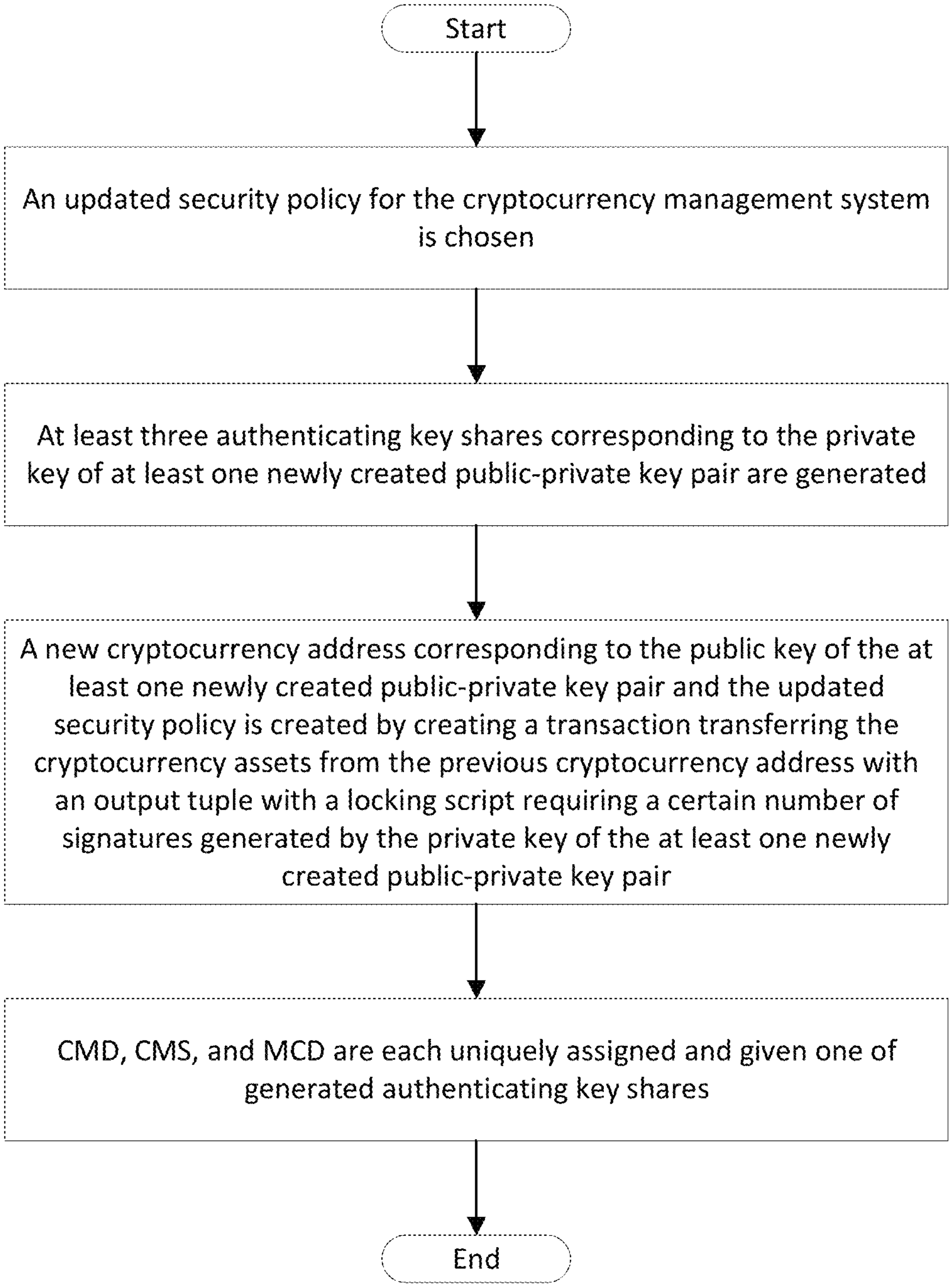
Start
An updated security policy for the cryptocurrency management system is chosen
At least three authenticating key shares corresponding to the private key of at least one newly created public-private key pair are generated
A new cryptocurrency address corresponding to the public key of the at least one newly created public-private key pair and the updated security policy is created by creating a transaction transferring the cryptocurrency assets from the previous cryptocurrency address with an output tuple with a locking script requiring a certain number of signatures generated by the private key of the at least one newly created public-private key pair
CMD, CMS, and MCD are each uniquely assigned and given one of generated authenticating key shares
End

FIG. 13

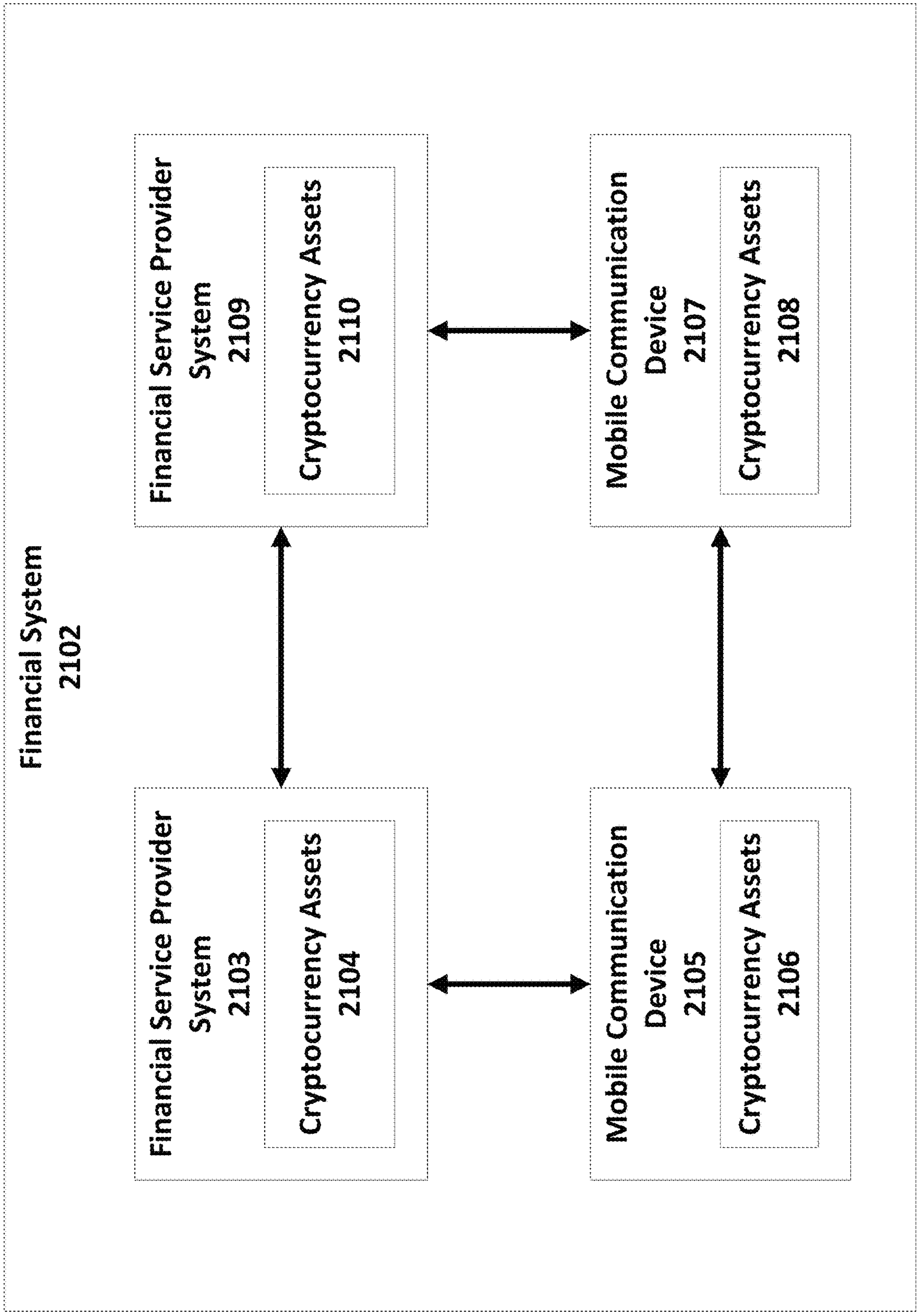
Financial System
2102
Financial Service Provider System
2109
Cryptocurrency Assets
2110
Mobile Communication Device
2107
Cryptocurrency Assets
2108
Financial Service Provider System
2103
Cryptocurrency Assets
2104
Mobile Communication Device
2105
Cryptocurrency Assets
2106

FIG. 14A

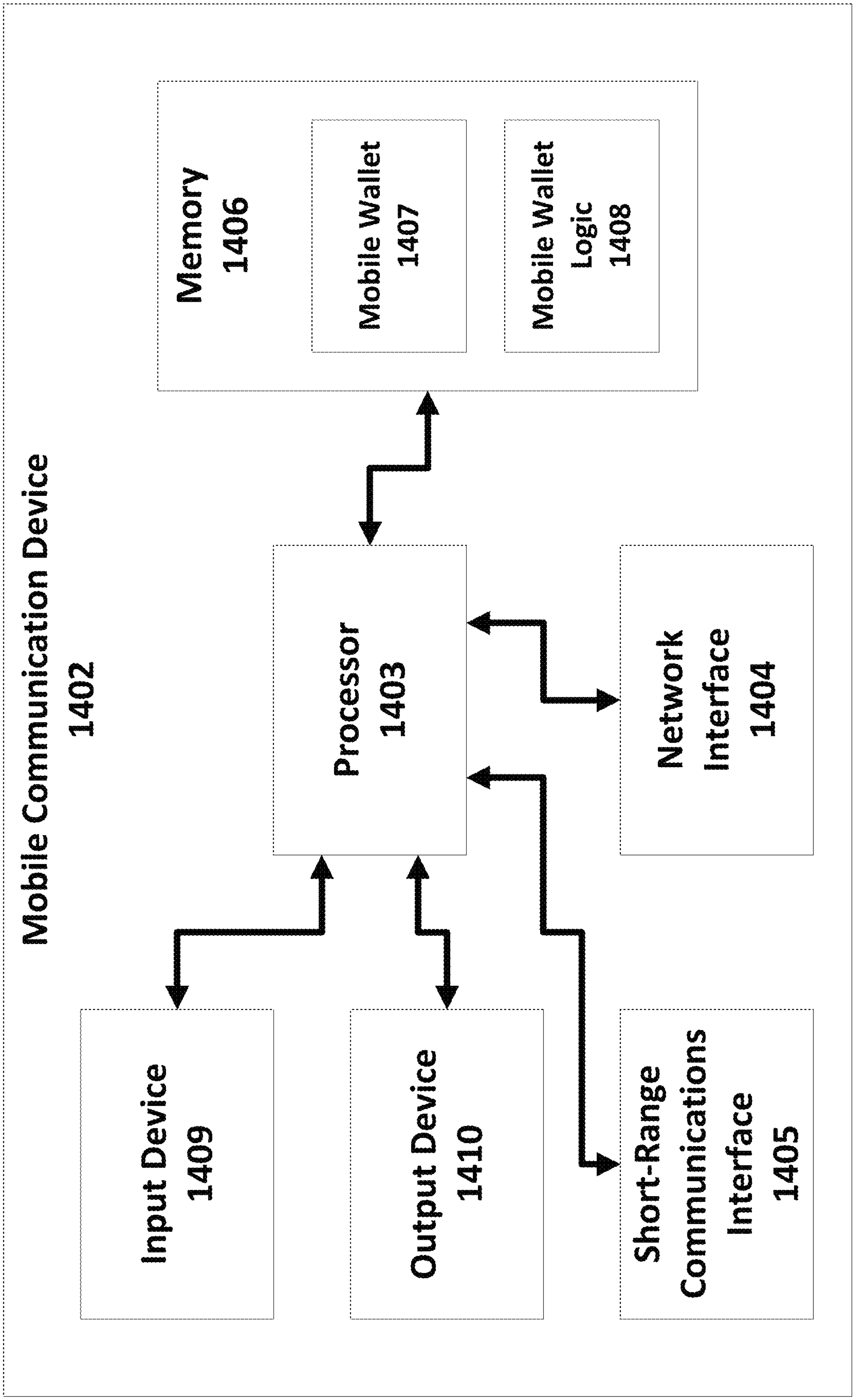
Mobile Communication Device
1402
Memory
1406
Mobile Wallet
1407
Mobile Wallet
Logic
1408
Processor
1403
Network
Interface
1404
Input Device
1409
Output Device
1410
Short-Range
Communications
Interface
1405

FIG. 14B

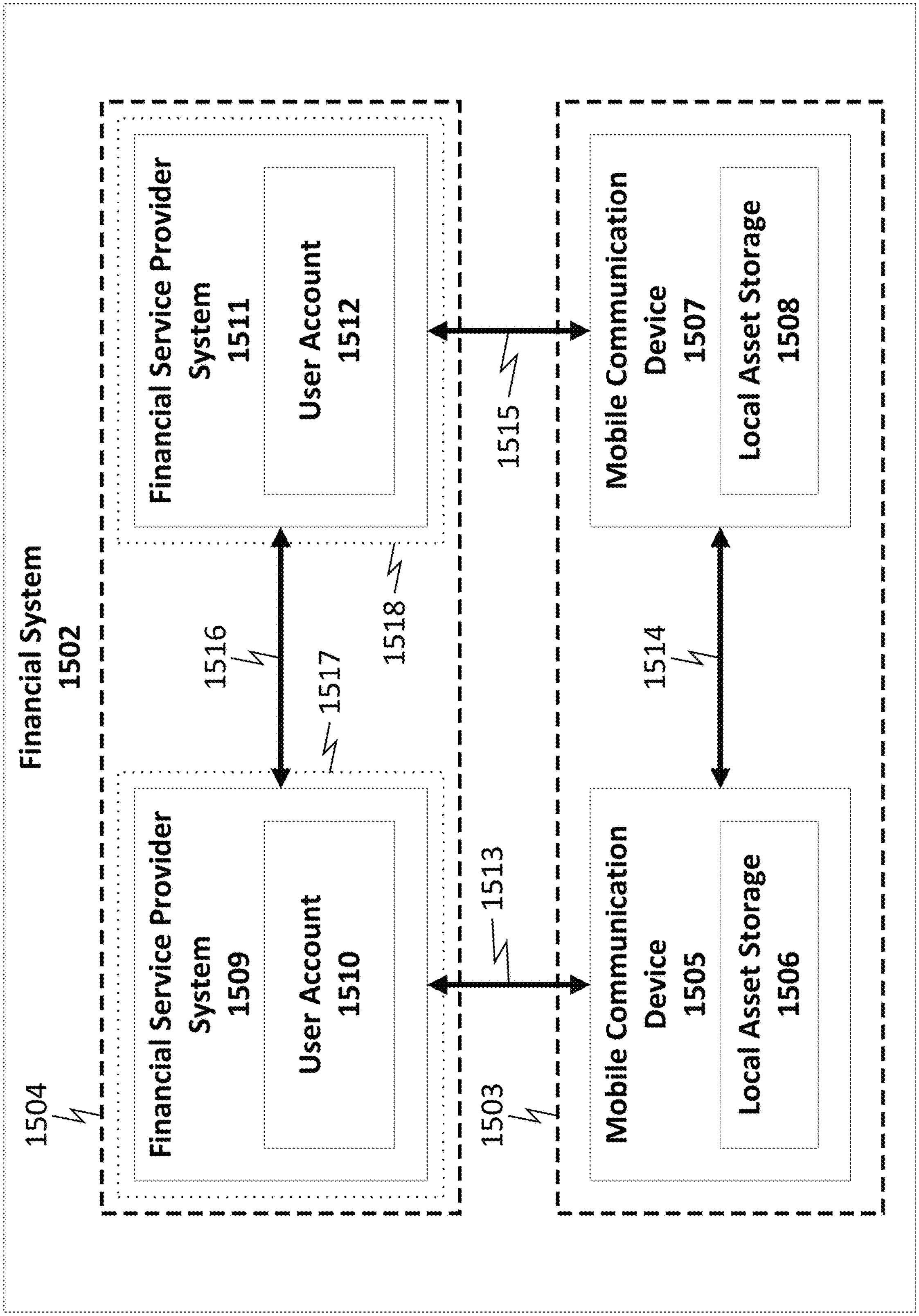
Financial System
1502
1504
Financial Service Provider
System
1509
User Account
1510
1516
1517
1518
Financial Service Provider
System
1511
User Account
1512
1513
1515
1503
Mobile Communication
Device
1505
Local Asset Storage
1506
1514
Mobile Communication
Device
1507
Local Asset Storage
1508

FIG. 15

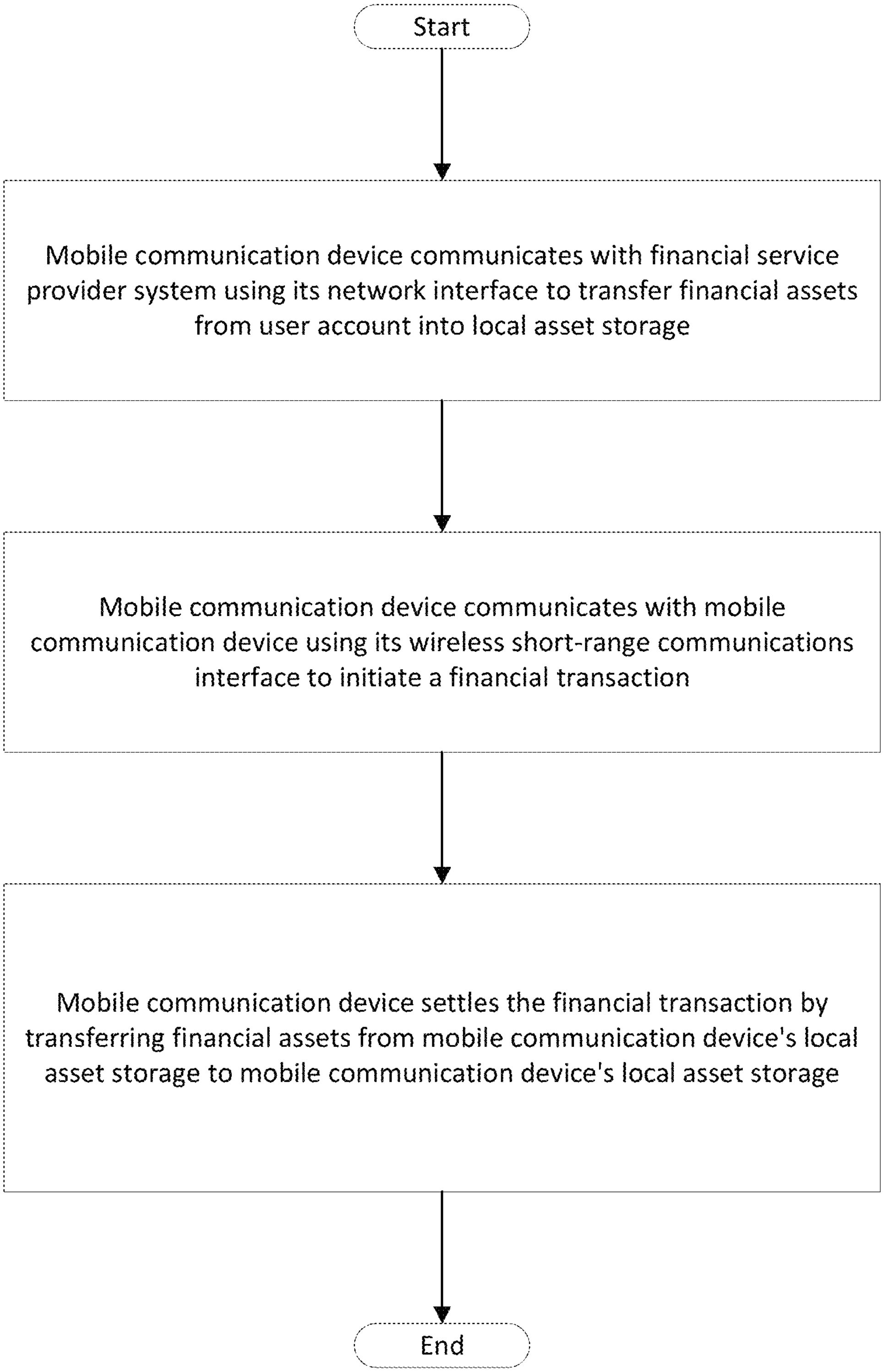
Start
Mobile communication device communicates with financial service provider system using its network interface to transfer financial assets from user account into local asset storage
Mobile communication device communicates with mobile communication device using its wireless short-range communications interface to initiate a financial transaction
Mobile communication device settles the financial transaction by transferring financial assets from mobile communication device's local asset storage to mobile communication device's local asset storage
End

FIG. 16

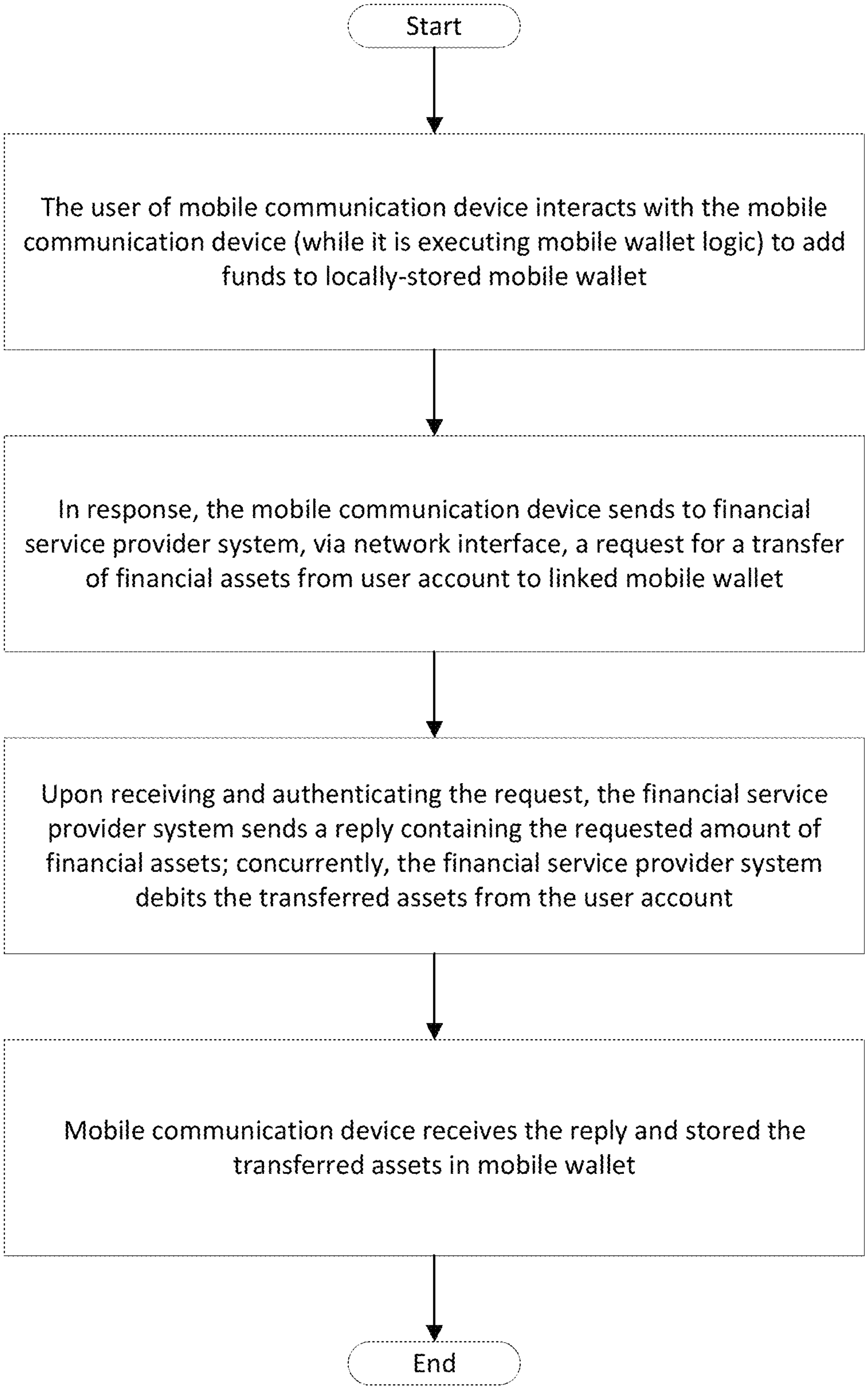
Start
The user of mobile communication device interacts with the mobile communication device (while it is executing mobile wallet logic) to add funds to locally-stored mobile wallet
In response, the mobile communication device sends to financial service provider system, via network interface, a request for a transfer of financial assets from user account to linked mobile wallet
Upon receiving and authenticating the request, the financial service provider system sends a reply containing the requested amount of financial assets; concurrently, the financial service provider system debits the transferred assets from the user account
Mobile communication device receives the reply and stored the transferred assets in mobile wallet
End

FIG. 17

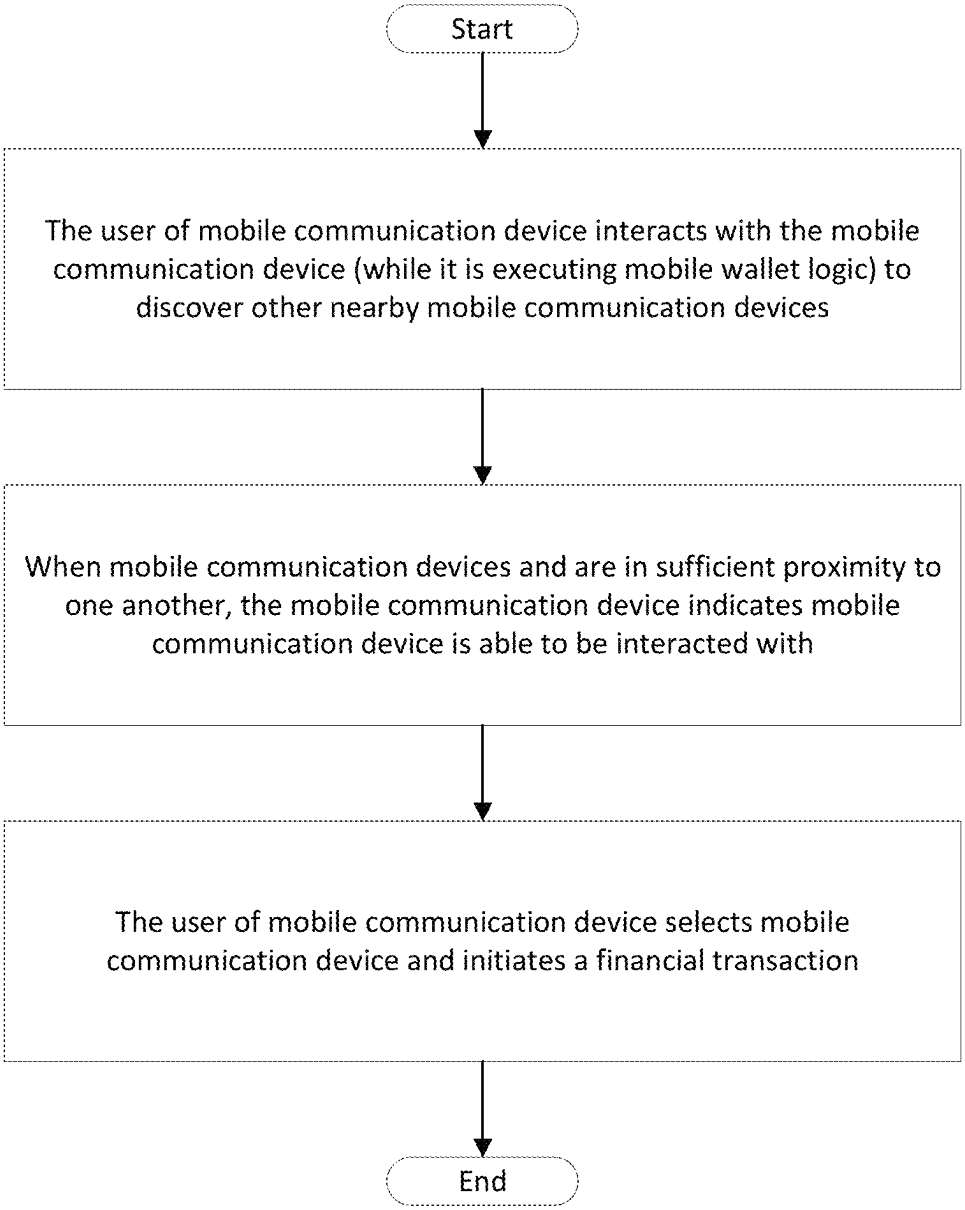
Start
The user of mobile communication device interacts with the mobile communication device (while it is executing mobile wallet logic) to discover other nearby mobile communication devices
When mobile communication devices and are in sufficient proximity to one another, the mobile communication device indicates mobile communication device is able to be interacted with
The user of mobile communication device selects mobile communication device and initiates a financial transaction
End

FIG. 18

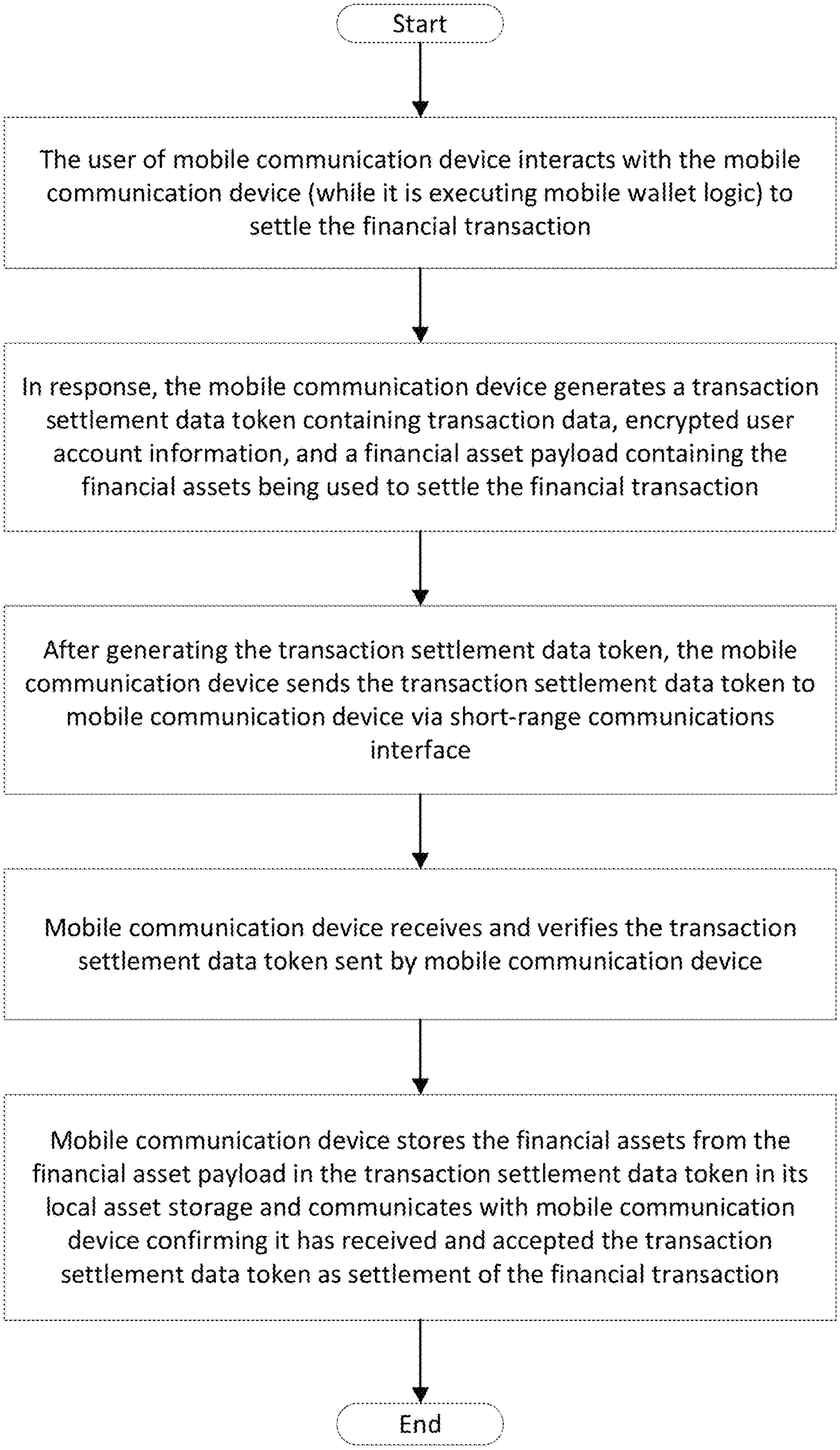
Start
The user of mobile communication device interacts with the mobile communication device (while it is executing mobile wallet logic) to settle the financial transaction
In response, the mobile communication device generates a transaction settlement data token containing transaction data, encrypted user account information, and a financial asset payload containing the financial assets being used to settle the financial transaction
After generating the transaction settlement data token, the mobile communication device sends the transaction settlement data token to mobile communication device via short-range communications interface
Mobile communication device receives and verifies the transaction settlement data token sent by mobile communication device
Mobile communication device stores the financial assets from the financial asset payload in the transaction settlement data token in its local asset storage and communicates with mobile communication device confirming it has received and accepted the transaction settlement data token as settlement of the financial transaction
End

FIG. 19

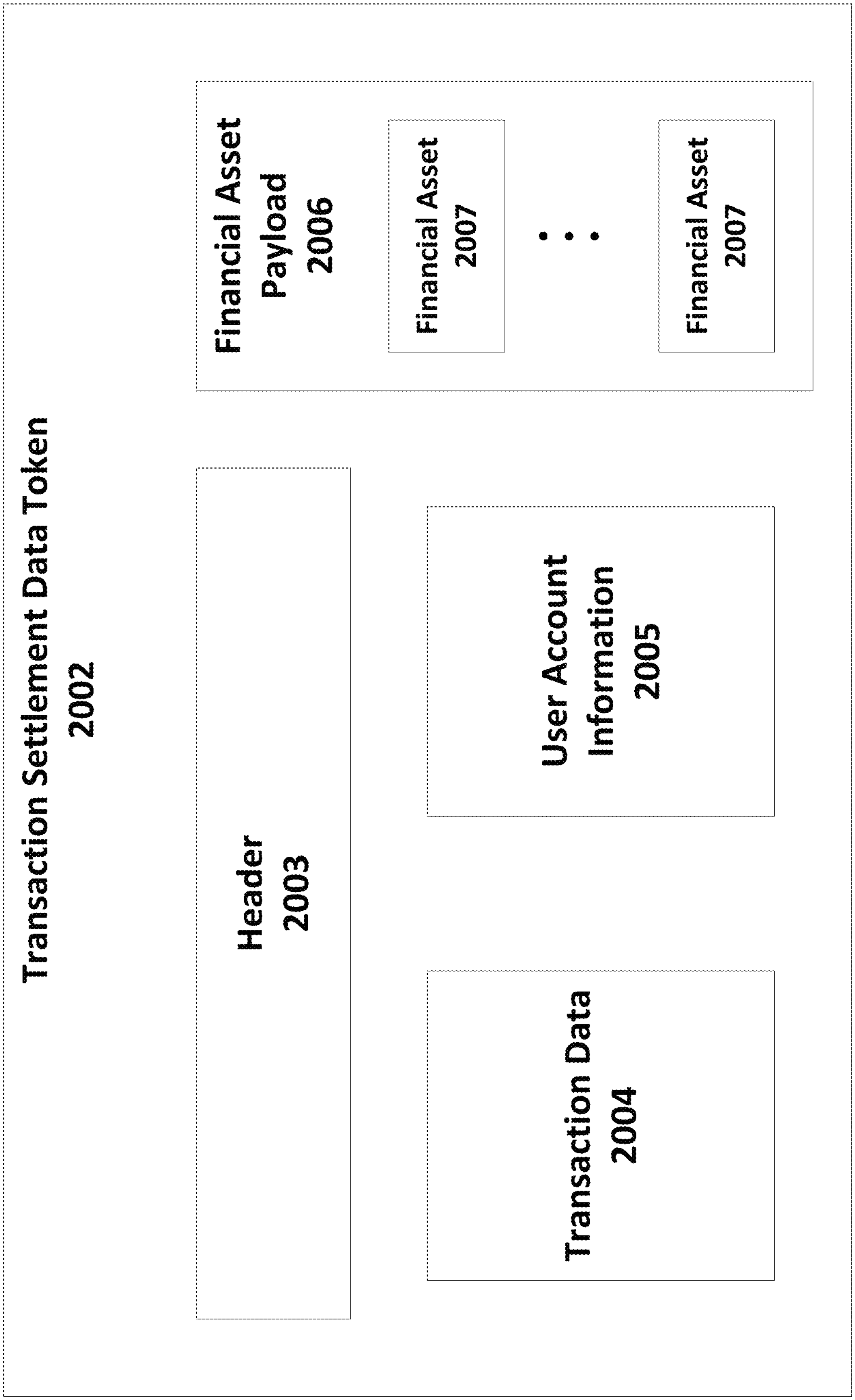
Transaction Settlement Data Token
2002
Header
2003
Financial Asset
Payload
2006
Financial Asset
2007
Financial Asset
2007
Transaction Data
2004
User Account
Information
2005

FIG. 20

SYSTEMS AND METHODS FOR MANAGING CRYPTOCURRENCY

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No. 63/216,969, filed on Jun. 30, 2021, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Cryptocurrency, such as Bitcoin, is increasing in popularity and has many advantages. In this regard, cryptocurrency provides a digital form of currency that may be transferred from one party to another through a global computer network, such as the internet, thereby facilitating the storage and transfer of financial assets for financial transactions. However, cryptocurrency suffers from several drawbacks or perceived problems or disadvantages that have limited its adoption. For example, some users may perceive cryptocurrency as being vulnerable to loss, either through deliberate actions by malicious actors or through accidental loss of necessary access credentials. As another example, some users may be deterred from using cryptocurrency because of perceived complexity in managing cryptocurrency holdings, especially with regards to securely maintaining the cryptographic keys needed to access and control cryptocurrency assets.

In particular, users of cryptocurrency often face a choice between third-party custody and self-custody. In third-party custody, the owner depends on a third party to hold information, such as private keys, that are used in establishing ownership and transferring cryptocurrency. Such a solution may be appealing to users who do not wish to be burdened with many of the complexities of holding, processing, and transferring information related to the cryptocurrency. However, many users may be concerned about the security measures used by third-party custodians to keep the cryptocurrency secure and also retaining the ability to access the cryptocurrency from the third-party custodians, such as during bankruptcy or other unanticipated events, as well as the loss of credentials required by the third-party custodians. With self-custody, the owner must wade through the technical complexities associated with managing cryptocurrency and also deal with security concerns. Many users may also be concerned about their ability to access cryptocurrency in the event of the loss of or damage to hardware used to store and otherwise manage the cryptocurrency.

Another perceived issue with cryptocurrency transactions and, more generally, any digital form of payment (e.g., debit cards, credit cards, or mobile payment services) is the reliance on an active internet connection. Unlike with physical money where the transfer of value is effected by direct exchange of a physical object (i.e., a banknote or coin) between the parties, the transfer of value for transactions involving payment cards or mobile payment services is often done by third-parties on behalf of the buyer. Thus, these exchanges require some form of communication with these third-parties, which is often done over the internet.

This requirement can be problematic for the many occasions where internet service is unreliable or unavailable when consumers are looking to make financial transactions. In such situations, a lack of internet connectivity can be a significant impediment to both the sellers looking to sell their goods or services and to the buyers looking to acquire them. In addition, the nature of many in-person events and transactions typically results in an increased risk of fraud for the buyers and sellers. For many transactions, including transactions between private parties, a person wishing to transfer funds to another person may be reluctant to provide the other person with private information, such as credit card or debit card numbers.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments and various aspects of the present disclosure are illustrated in the following detailed description and the accompanying figures. The various features shown in the figures may not be drawn to scale.

FIG. **1** is a block diagram illustrating a cryptocurrency management system, according to an exemplary embodiment of the present disclosure.

FIG. **2** is a block diagram illustrating a cryptocurrency network, such as is depicted by FIG. **1**.

FIG. **3** is a block diagram illustrating a cryptocurrency blockchain, such as is depicted in FIG. **2**.

FIG. **4** is a block diagram illustrating a cryptocurrency transaction, such as is depicted in FIG. **3**.

FIG. **5** is a flowchart illustrating an exemplary method of using a cryptocurrency management system, such as is depicted by FIG. **1**, to manage cryptocurrency assets.

FIG. **6** is a block diagram illustrating a cryptocurrency management device, such as is depicted in FIG. **1**.

FIG. **7** is a block diagram illustrating a cryptocurrency management server, such as is depicted in FIG. **1**.

FIG. **8** is a block diagram illustrating a mobile communication device, such as is depicted in FIG. **1**.

FIG. **9** is a diagram illustrating a front view and back view of an exemplary mobile communication device, such as is depicted in FIG. **8**.

FIG. **10** is a flowchart illustrating an exemplary method of configuring a cryptocurrency management system to begin managing cryptocurrency assets.

FIG. **11** is a flowchart illustrating an exemplary method of initiating and authenticating a cryptocurrency transaction.

FIG. **12** is a flowchart illustrating an exemplary method of finalizing an authenticated cryptocurrency transaction with a cryptocurrency network, such as the cryptocurrency network of FIG. **1**.

FIG. **13** is a flowchart illustrating an exemplary method of modifying the security policy of a cryptocurrency management system.

FIG. **14**A is a block diagram illustrating a financial system, according to an exemplary embodiment of the present disclosure.

FIG. **14**B is a block diagram illustrating a mobile communication device, according to an exemplary embodiment of the present disclosure.

FIG. **15** is a more detailed block diagram of the financial system shown in FIG. **14**A.

FIG. **16** is a flowchart illustrating an exemplary method of locally conducting a financial transaction.

FIG. **17** is a flowchart illustrating an exemplary method of transferring funds from a financial service provider to a mobile wallet for a mobile communication device.

FIG. **18** is a flowchart illustrating an exemplary method of locally initiating a financial transaction.

FIG. **19** is a flowchart illustrating an exemplary method of locally settling a financial transaction.

FIG. **20** is a block diagram illustrating a data token used to locally settle a financial transaction, such as the data token described in FIG. **19**.

DETAILED DESCRIPTION

The present disclosure generally pertains to system and methods for managing and using digital financial assets, such as cryptocurrency. In some embodiments of the present disclosure, multiple independent devices mutually cooperate to control cryptocurrency assets in a secure manner. In this regard, each of these devices may store a unique authenticating key share associated with the cryptocurrency assets, and the cryptocurrency assets may be configured such that a certain minimum number of these authenticating key share are required to transfer the cryptocurrency assets. The use of multiple authenticating key shares spread across multiple distinct devices may reduce the likelihood of loss stemming from a hardware failure or reduce the likelihood of an attacker successfully gaining access to the cryptocurrency assets.

In some embodiments, the number and characteristics of these authenticating key share storing devices (e.g., portable vs stationary, user custody vs third-party custody), as well as how many authenticating key shares are required to authorize a transaction, may be tailored to balance a user's preferences for reliability of access versus security and for third-party custody versus self-custody. For example, a user who prioritizes security may require a greater number of authenticating key shares for authorizing a transaction. In contrast, a user prioritizing reliability of access may require a fewer number of authenticating key shares. Over time, the minimum number of authenticating key shares sufficient to authorize a transaction may change in an effort to enable recovery from a failed device or a loss of credentials.

With regards to prioritizing self-custody, a user may opt only to utilize devices to which the user has direct access to (e.g., within the user's possession). In contrast, a user wishing to have at least more flexibility or robustness to device failures may opt to utilize one or more devices of a third party, such as a trusted agent. In addition, over time, the devices or authenticating key shares that may be used to authenticate a transaction may change in an effort to enable recovery from a failed device or a loss of credentials.

The devices used to manage the authenticating key shares may also be configured so as to authenticate themselves to one another in a manner that is easy and convenient to the user. For example, each pair of the devices may have a shared secret (e.g., a shared symmetric key) between themselves that is independent of the authenticating key shares used to authorize the cryptocurrency transactions. This can allow a user to authenticate himself or herself to one of these devices by, e.g., providing a password or other form of verification such as a fingerprint. This device may then authenticate itself to the other devices using the shared secret and the user provided verification in a manner that is transparent to the user. Thus, from the user's perspective, the process of authenticating a transaction involving the transfer of financial assets is simplified. The net effect of these techniques and functions, as described in more detail below, is to reduce the chance that access to the cryptocurrency assets are lost while improving the ease of conducting a transaction using the cryptocurrency funds.

A system in accordance with some embodiments of the present disclosure employs a cryptocurrency management device (CMD), a cryptocurrency management server (CMS), and a mobile communication device (MCD) to jointly store and control the cryptographic keys used to generate valid transactions involving a cryptocurrency address. The cryptocurrency address may be configured to generally require signatures produced by a certain number (e.g., quorum) of these devices, thereby improving the security of the cryptocurrency assets. Moreover, the distribution of authority across these devices reduces the chance of a loss of access to the cryptocurrency assets resulting from a physical loss or failure of a particular device. The manner in which the devices communicate with one another, as well as their ability to implement more advance security directives, also improves the ease and efficiency of a user conducting a transaction using the cryptocurrency funds from the cryptocurrency address.

In some embodiments of the present disclosure, an MCD may be used to physically store digital financial assets. These financial assets may be obtained from an account at a financial service provider and stored as data in a mobile wallet that is linked to that account and that is itself located within the MCD's non-volatile memory. Because these assets are stored on the MCD itself, they may be used to settle financial transactions (e.g., pay for goods being bought from a seller) without needing to communicate with the financial service provider (or any other non-local entity besides the other participant in the financial transaction). Thus, the MCD may settle financial transactions directly with another device (e.g., another MCD), without requiring a concurrent internet connection. Mechanistically, this involves transferring some portion of the locally stored financial assets to a mobile wallet on the other device.

In addition to the ability to conduct financial transactions even in the absence of a concurrent internet connection, the receiving party can also reliably accept the assets as payment without needing to communicate with a financial service provider (or any other non-local entity besides the other participant in the financial transaction) and without requiring exposure of sensitive information from the other participant. In addition, linking the user's account information with the mobile wallet (and with the transferred financial assets) allows the receiving party to avoid potential double-spend attacks.

Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings. The following description refers to the accompanying drawings in which the same numbers in different drawings represent the same or similar elements unless otherwise represented. The implementations set forth in the following description of exemplary embodiments do not represent all implementations consistent with the invention. Instead, they are merely examples of apparatuses and methods consistent with aspects related to the invention as recited in the appended claims. Particular aspects of the present disclosure are described in greater detail below.

FIG. **1** is a simplified block diagram of a cryptocurrency management system. As shown by the figure, a cryptocurrency management system **102** may comprise a cryptocurrency management device (CMD) **103**, a cryptocurrency management server (CMS) **104**, and a mobile communication device (MCD) **105**. Also shown by the figure is a cryptocurrency network **203** and a cryptocurrency address **107** associated with (one or more transactions in) the cryptocurrency network **106**. In general, the MCD **105** may interact with the CMD **103** and the CMS **104** to, among other things, generate and submit valid cryptocurrency transactions. As part of this process, the MCD **105** may also interact with the cryptocurrency network **203**.

In general, each of the devices **103**, **104**, and **105** may also comprise a cryptocurrency account (CA) private key share (i.e., CA private key shares **108**, **110**, and **112**) and control logic (i.e., control logic **109**, **111**, and **113**). As described further below, the CA private key shares **108**, **110**, and **112** are cryptographic keys associated with the private key of the public-private key pair (the private key of one of the public-private key pairs, for multi-signature addresses) of a cryptocurrency address (e.g., cryptocurrency address **107**). As also described further below, the control logics **109**, **111**, and **113** may contain instructions that can be executed by their device's respective processor **603** to perform various functions of that device.

At a high level, the cryptocurrency management system **102** works to manage the cryptocurrency address **107** by controlling use of the cryptocurrency funds associated with the cryptocurrency address **107** in a transaction. In this regard, the cryptocurrency management system **102** can be thought of as an association of devices or systems that (1) each have been distributed a portion of the authority to control the cryptocurrency address **107** and (2) are configured to cooperate with one another to use their collective authority to control (e.g., generate and submit a transaction involving) the cryptocurrency address **107**. In other words, the ability to manage the cryptocurrency address **107** is split between the CMD **103**, the CMS **104**, and the MCD **105**. In some embodiments, the CMD **103**, the CMS **104**, and the MCD **105** communicate with one another and agree to a transaction before the signatures for the transaction are obtained and an authenticated transaction is generated and submitted to the cryptocurrency network **203**.

Before explaining the functioning of the cryptocurrency management system **102** in more detail, a basic overview of the terminology and general architecture of cryptocurrencies is useful. FIG. **2** is a simplified schematic giving a basic overview of the general architecture of cryptocurrencies. As shown by the figure, a cryptocurrency architecture **202** comprises a cryptocurrency network **203** that has a plurality of cryptocurrency nodes **204** (shown in FIG. **2** as cryptocurrency nodes **204***a*, **204***b*, **204***c*, **204***d*, and **204***e*). In general, the cryptocurrency nodes **204** may communicate with one another over various networks **205** (shown in FIG. **2** as networks **205***a*, **205***b*, **205***c*, **205***d*, **205***e*, **205***e*, and **205***f*), such as the internet.

With regards to their purpose, the cryptocurrency nodes **204** generally work to modify a cryptocurrency blockchain **209** according to the procedures dictated by a cryptocurrency protocol **208**. Towards this end, each node is generally associated with one or more processors (shown in FIG. **2** for cryptocurrency node **204***b* as processor **206***b*) and a memory unit (shown in FIG. **2** for cryptocurrency node **204***b* as memory **207***b*). Stored in each cryptocurrency node's memory is an executable form of the cryptocurrency protocol **208** and a copy of the cryptocurrency blockchain **209**. Together, the cryptocurrency network **203**, the cryptocurrency protocol **208**, and the cryptocurrency blockchain **209** comprise the overall cryptocurrency architecture **202**.

More precisely, the cryptocurrency blockchain **209** (also known as a cryptocurrency ledger) is a type of (distributed and decentralized) database where the stored data is a series of records (i.e. transactions) that are grouped into cryptographically linked lists called blocks. These records generally concern amounts of a digital asset, sometimes called "coins" or "tokens", created by the cryptocurrency architectures **202**. The cryptocurrency protocol **208** is a set of instructions/rules (e.g., a program) dictating how the cryptocurrency blockchain **209** is processed (e.g., how new transactions are added). Generally speaking, the various cryptocurrency nodes **204** each process the cryptocurrency blockchain **209** according to the cryptocurrency protocol **208**.

Because of the lack of a central authority in most cryptocurrency architectures **202**, a consideration for the design of the cryptocurrency architectures **202** (i.e., the rules of cryptocurrency protocol **208**) is how new blocks and transactions are added to the cryptocurrency blockchain **209**. More precisely, the consideration is not just how new blocks and transactions are added to the cryptocurrency blockchain **209**, but how the cryptocurrency nodes **204** can come to a consensus on the addition of a new block (and the corresponding transactions within that block).

Broadly speaking, a newly added block to a blockchain contains within itself a list of new transactions and a cryptographic hash of both those new transactions and of the previously added block. This hash may be required to meet certain criteria on which the cryptocurrency nodes **204** generally work to satisfy. This attempt produces a new block by generating a hash satisfying the criteria specified in the cryptocurrency protocol **208**. Such a process is often referred to as "mining." The requirements on the hash of a new potential block is the primary mechanism by which the cryptocurrency nodes **204** are able to cooperatively agree on when a new block is added to the blockchain **209**.

More precisely, many cryptocurrency architectures **202** are configured (i.e., their cryptocurrency protocol **208** requires) such that a new block is required to meet at least two requirements. First, the transactions within the new block must be valid (i.e., satisfy certain criteria specified by the cryptocurrency protocol **208**). Second, the new block must include the hash of the previous block and the transactions within the new block that satisfy certain criteria specified by the cryptocurrency protocol **208**. If and when a cryptocurrency node **204** finds such a hash, it transmits the new block to the rest of the cryptocurrency nodes **204** in the cryptocurrency network **203**, which validate the new block and, upon confirming its validity, add it to their copy of the cryptocurrency blockchain **209**. The cryptocurrency nodes **204** then continue working using the updated cryptocurrency blockchain **209**.

FIG. **3** is a simplified diagram of the structure of the cryptocurrency blockchain **209**. As shown by the figure, the cryptocurrency blockchain **209** comprises a plurality of blocks **303** (shown in FIG. **3** as blocks **303***a*, **303***b*, and **303***c*). Each block **303** comprises a series of transactions **304** and a validating hash. The validating hash is a hash of the cryptocurrency transactions **304** and the validating hash of the immediate prior block **303** whose value meets certain criteria defined by the associated cryptocurrency protocol **208**.

It is also useful to note the general structure of the transactions **304**. Like many other transactions, at a conceptual level, each transaction **304** involves an input (here of cryptocurrency coins) and an output (here also of cryptocurrency coins) (e.g., as shown in FIG. **4** below). Generally speaking, for a cryptocurrency system, the output is a certain number of cryptocurrency coins and locking conditions (specified in what is known as a locking script (e.g., as shown in FIG. **4** below) that must be satisfied to use those coins as input in a future transaction. The input, then, is the identity of a previous (unspent) transaction and data satisfying its associated locking condition. In this way, every transaction ultimately changes the locking condition of a cryptocurrency coin (or at least a portion of a cryptocurrency coin).

FIG. **4** is a simplified schematic of the structure of a cryptocurrency transaction **304**. As shown by the figure, a cryptocurrency transaction **304** includes a transaction input **403** and a transaction output **405**. The transaction is the source of cryptocurrency coins for use in the output while the output specifies new locking conditions for those identified cryptocurrency coins. More formally, the transaction input **403** includes one or more input tuples **404**. In turn, each input tuple **404** has a previous transaction pointer and an unlocking script. The previous transaction pointer of an input tuple **404** identifies a previous transaction whose output has not yet been spent while the unlocking script satisfies the unlock conditions specified by that previous transaction. Similarly, the transaction output **405** includes one or more output tuples **406**. In turn, each output tuple **406** has an output value and a locking script. The output value identifies an amount of cryptocurrency coins while the locking script identifies lock conditions for those cryptocurrency coins to be used in a future transaction.

Thus, a cryptocurrency transaction does not necessarily involve an "account" or "address" and, in general, neither does the overall cryptocurrency architecture **202**. Rather, in some embodiments, all that changes is the unlocking condition needed to use a cryptocurrency coin as input to a future transaction. That said, however, many locking scripts (and their associated unlocking scripts) do give rise to something closely analogous to an account or address. Specifically, a common locking script requirement is use of a private key corresponding to a public key listed in the locking script. These locking scripts are often called "pay-to-public-key" (or just "to-public-key") locking scripts. More precisely, the locking script usually lists a public key and requires that a future referencing transaction produce (in its unlocking script) a hash of the new transaction encrypted by the public key's corresponding private key (called a "signature"). Because of the nature of public-private key cryptography, producing an encrypted hash that, when decrypted by the public key, yields the correct hash for the new transaction generally requires possession of the associated private key. Thus, to verify the requirement is met, one first independently generates a hash of the proposed new transaction. One then decrypts the provided signature with the public key listed in the locking script and compares the two hashes. A match means the locking script is satisfied.

The public key specified in a "pay-to-public-key" locking script gives rise to the notion of a cryptocurrency address (or just an "address"). This is broadly because of two reasons. The first is because the holder of the corresponding private key can use (i.e., effectively owns) the cryptocurrency coins from any "pay-to-public-key" locking script using the same public key. This is analogous to how the owner of a financial account can spend any funds in the account. The second reason is that the public key is essentially unique to its corresponding private key. Because of certain mathematical properties of asymmetric cryptography, it is computationally infeasible to generate a public-private key pair with the public key having a specific desired value. Therefore, a given public key has one corresponding private key and, so long as the private key has not been leaked, has a one-to-one correspondence with some controlling entity. This is similarly analogous to an address or account number, which usually uniquely identifies a recipient.

A similar concept known as a "multi-signature address" arises from the use of locking scripts similar to a "pay-to-public-key" locking script with the change of their being multiple public-keys listed. These locking scripts (referred to here as a "pay-to-public-keys" locking script) list several public keys and require the production of a certain number of signatures from corresponding private keys. Thus, the process is essentially the same as with the a "pay-to-public-key" locking script except that multiple private keys are

used to make multiple signatures that each must be a match for a listed private key for the locking script condition to be satisfied. The idea of the "multi-signature address" again arises from the combination of the listed public keys or from some derivate derived from them.

Note that, for a "pay-to-public-keys" locking script (i.e., for a multi-signature address), the number of signatures required can be less than the number of listed private keys. For example, a "pay-to-public-keys" locking script may list 7 public keys but specify that production of signatures corresponding to four (or more) of those public keys is sufficient.

As previously mentioned, cryptocurrencies are increasingly being used in various financial transactions. The reasons for this are varied, but are in significant part due to the advantages inherent to cryptocurrencies, such as improved privacy compared to many other digital forms of payment.

However, cryptocurrencies suffer from several disadvantages. In large part, these disadvantages stem from the cryptographic scheme above. Broadly speaking, having the information listed in the unlocking script for given cryptocurrency assets is sufficient to have "control" over those assets. Usually, this is a private key corresponding to the public key listed in the associated locking script. The effect of this, however, is that one should maintain access to the private key and should not allow other untrusted users to access the private key.

Pragmatically, these private keys are long strings of numbers that are effectively too long to be memorized. Consequently, these private keys are often stored on some physical or digital medium that is accessible to the user. However, this introduces a few problems. First, it renders the cryptographic keys vulnerable to being lost or otherwise made inaccessible due to loss or failure of the hardware on which they are stored. Because obtaining cryptographic funds generally requires satisfying the unlocking script associated with those funds, there is usually no way to recover access to a cryptocurrency address if the corresponding private key is lost. In other words, if the locking script requires a digital signature from a private key corresponding to a certain public key, if the private key is lost and no other copies are available, those cryptocurrency funds are essentially permanently lost.

Second, storage of private keys on physical or digital media makes the cryptocurrency assets uniquely vulnerable to theft through digital means. Specifically a malicious party who is able to gain access to the private keys may use such keys to access the cryptocurrency assets associated with the keys.

One solution is to use offline storage, but this makes the system more difficult to use in a transaction. Another method is to store the private key with a third-party. However, this gives up advantage of control over the cryptocurrency assets and requires a user to trust the associated third-party.

In some embodiments of the present disclosure, a cryptocurrency management system **102**, such as is depicted by FIG. **1**, increases the security of an individual's possession and control over their Bitcoin wallet without overly encumbering ease-of-use or surrendering control over a wallet to a third-party. At a high-level, many of the benefits of the cryptocurrency management system **102** can be attributed to the (differing) natures of the CMD **103**, CMS **104**, and the MCD **105** and the specifics of how the devices cooperate with one another to manage the cryptocurrency address **107**. Because the nature of the devices means that they may have differing advantages and disadvantages (e.g., more or less likely to be lost, more or less in control of a user, etc.), requiring the mutual cooperation of these devices can combine their advantages (and mitigate their disadvantages), resulting in increased reliability and security while maintaining ease-of-use.

The exact trade-off between reliability, security, and ease-of-use may depend on how the devices of the cryptocurrency management system **102** are configured to work together to manage the cryptocurrency address **107**. One potentially relevant aspect is if the CMD **103**, CMS **104**, and the MCD **105** may communicate directly with one another or if one or more the devices may (or possibly must) communicate through an intermediary. If an intermediary is needed for one or more devices, another relevant aspect is the identity of the intermediary, particularly if the intermediary is itself one of the devices of the cryptocurrency management system **102** (e.g., if the intermediary is the CMD **103**, CMS **104**, or the MCD **105**). A related aspect is if the CMD **103**, CMS **104**, and the MCD **105** jointly participate in carrying out (as opposed to simply, after proper authentication, authorizing) a task (e.g., a transaction involving the cryptocurrency address **107**) or if one of the devices acts as a coordinator.

Another potentially relevant aspect is the nature of the communication channels available to the CMD **103**, CMS **104**, or the MCD **105**, such as if the communication channels are short-range only or if they all include long-range communication channels. Also potentially relevant is what is required by each of the CMD **103**, CMS **104**, or the MCD **105** in order to cooperate with any of the other devices with regards to the cryptocurrency address **107**.

Also a potentially relevant aspect is the technical means used to distribute authority over the cryptocurrency address **107**. For example, in some embodiments a multi-signature cryptocurrency address may be used, with the authenticating key shares used by the cryptocurrency management system to manage the cryptocurrency address **107** being the address's associated private keys. As another example, in some embodiments a single-signature cryptocurrency address may be used, with the authenticating key shares being "shares" of the private key generated using a threshold secret sharing method to divide information about the private key.

As a more concrete illustration, FIG. **5** illustrates the operation of a cryptocurrency management system **102** where the MCD **105** is acting as the coordinator and where the cryptocurrency address **107** is a multi-signature address whose private keys are used as the authenticating key shares distributed across the CMD **103**, CMS **104**, or the MCD **105**. More precisely, FIG. **5** is a flowchart of an exemplary method of using a cryptocurrency management system **102** to manage cryptocurrency assets, similar to the description above. Briefly, the process involves configuring the cryptocurrency management system **102** to have sufficient information to manage the cryptocurrency address **107**, initiating a financial transaction using the MCD **105**, communicating with the CMD **103** or CMS **104** to obtain a second authorizing signature for the transaction, and using the obtained signature, and an authorizing signature generated by the MCD **105**, to generate a fully authenticated cryptocurrency transaction. Note that, in other embodiments, other numbers of signatures and/or signatures from different devise may be used authorize a transaction.

As shown by the figure, the process starts with initializing the cryptocurrency management system **102** to manage the cryptocurrency address **107** for cryptocurrency asset. Note here that, as mentioned above, a cryptocurrency address refers to the collection of (unspent) cryptocurrency transactions whose outputs have a "pay-to-public-keys" locking script that references the public keys associated with that cryptocurrency address. Correspondingly, the cryptocurrency address **107** refers to a collection of (unspent) cryptocurrency transactions whose output has a "pay-to-public-keys" locking script that references the public keys associated with cryptocurrency address **107**.

After the cryptocurrency management system **102** is initialized, the cryptocurrency management system **102** can be used to effect a transaction involving the cryptocurrency address **107**. Specifically, the MCD **105** initiates a transaction involving the cryptocurrency address **107** and generates a first authenticating signature for the transaction. One consideration of this process is how the authority is split between the CMD **103**, the CMS **104**, and the MCD **105** and how the CMD **103**, the CMS **104**, and the MCD **105** cooperate with one another to jointly wield this authority. In some embodiments, authority may be split between the components of the cryptocurrency management system **102** by splitting the private keys associated with the cryptocurrency address **107** and giving a respective one of them to the CMD **103**, the CMS **104**, and the MCD **105**. For example, in the simplest case, there are three private keys associated with the cryptocurrency address **107** and each of the CMD **103**, the CMS **104**, and the MCD **105** is given a respective one of them such that the CMD **103**, the CMS **104**, and the MCD **105** do not have the same private keys.

Additionally, to generate the authenticating signatures, the CMD **103**, CMS **104**, and the MCD **105** may employ various digital signature schemes to create a cryptographically secure digital signature of the transaction (or a relevant portion of the transaction) using the devices' respective authenticating key shares. For example, if the transaction involves the Bitcoin network, the CMD **103** may generate the first authenticating signature by using the elliptic curve digital signature algorithm (ECDSA) on each input tuple **404** in the proposed transaction.

After the transaction is initiated, the MCD **105** may work to obtain the information (e.g., the signatures) for authorizing the transaction. To this end, the MCD **105** may communicate with other components of the cryptocurrency management system **102** to obtain their authorization for the initiated transaction. Specifically, the MCD **105** may communicate with either (or possibly both) the CMD **103** and the CMS **104** to obtain a second authenticating signature (and possibly a third authenticating signature) for the transaction. As discussed in more detail below, this may involve the MCD **105** authenticating itself to the device it is communicating with to prove its identity and, possibly, that an authorized user has initiated the transaction. The device that the MCD **105** is authenticating itself to may also provide information to the MCD **105** authenticating the device's identity.

The components of the cryptocurrency management system **102** may employ a variety of techniques to communicate with one another. For example, in the embodiment discussed in FIG. **5**, the CMD **103** and the CMS **104** do not communicate directly with one another, but instead communicate only with the MCD **105**, which is acting as a coordinator for the financial transaction. In other embodiments, different communication schemes may be used. For example, in some embodiments either the CMD **103** or the CMS **104** may act as the coordinator, with communications from other devices going only to the coordinating device. In other embodiments, the CMD **103**, CMS **104**, and MCD **105** may directly communicate with one another over the internet.

In addition, the cryptocurrency management system **102** may employ a variety of communication channels to physically transmit information between the CMD **103**, CMS **104**, and MCD **105**, along with any other components of the cryptocurrency management system **102**. Additionally, each pair of devices may employ a different communication channel. For example, in some embodiments the CMS **104** and the MCD **105** may communicate with one another over the internet, employing some form of long-range communication to facilitate the communication (e.g., cellular towers, network routers, Wi-Fi hots spots, or other types of access points). On the other hand, in some embodiments the CMD **103** and the MCD **105** may communicate with one another only over short-range, peer-to-peer communication channel (e.g., Bluetooth, Near Field Communication (NFC), or radio frequency identification (RFID)). This may require that the CMD **103** and the MCD **105** be in physical proximity to one another, which may enhance security by increasing the difficulty of a malicious actor somehow compromising the CMD **103**. Of course, in some embodiments the CMD **103** and the MCD **105** may communicate at long-range, such as by communicating over the internet.

After receiving the request from the MCD **105**, the CMD **103** may (assuming that it accepts the request) generate the requested authenticating signature. Specifically, the CMD **103** may generate the second authenticating signature and then transmit the second authenticating signature to the MCD **105**. This may involve generating a signed hash of the transaction proposed in the request from the MCD **10**.

Similarly, after receiving the request from the MCD **105**, the CMS **104** may (assuming that it accepts the request) generate the requested authenticating signature. Specifically, the CMS **104** may generate the second authenticating signature and then transmit the second authenticating signature to the MCD **105**.

Eventually, the MCD **105** may obtain the second and third authenticating signatures from the CMD **103** and the CMS **104**. After they are received, the MCD **105** may combine them with the first authenticating signature stored by the MCD **105** to generate a fully authenticated cryptocurrency transaction. Specifically, the MCD **105** may obtain the second and third authenticating signatures and, after they are obtained, use the second and third authenticating signatures, along with the first authenticating signature, to generate a fully authenticated cryptocurrency transaction.

After it is generated, the fully authenticated cryptocurrency transaction can be submitted for processing. Specifically, the MCD **105** may submit the authenticated cryptocurrency transaction request to the cryptocurrency network **203**, which then processes the request, thereby finalizing the transaction.

Note that the method described here is performed with the MCD **105** as the initiator of the transaction. However, in general, either of the CMD **103** or the CMS **104** may alternatively initiate the transaction. In such a case, the initiating device or system may perform the same or similar steps described above as performed by the MCD **105**.

Also note that, in some embodiments, the MCD **105** may not itself store one of the authenticating key shares and may not itself generate one of the authenticating signatures. Rather, the MCD **105** may perform the function described above of communicating with and obtaining authenticating signatures from other devices of the cryptocurrency management system **102** to obtain a quorum number of authenticating signatures without itself contributing an authenticating signature to that quorum.

Note that in some embodiments the number of authenticating signatures may be conditional and, in particular, may be conditional on the passage of time. For example, in some embodiments the locking script in the most recent transaction involving the cryptocurrency address may specify that, in addition to being satisfied by two signatures produced by any two of the three private keys distributed to the CMD **103**, the CMS **104**, and the MCD **105**, the locking script may also, conditional on the current time being a specified amount of time from the transaction's submission date or after a particular time in the future, be satisfied by only a single signature produced by any one of the three private keys distributed to the CMD **103**, the CMS **104**, and the MCD **105**. This may be useful in preventing loss of access to the cryptocurrency address due to the loss or failure of one of the CMD **103**, the CMS **104**, or the MCD **105**. By automatically reducing the quorum when there is no user-initiated activity (as might be the case when a user could not conduct any activity because of a missing or failed device), this may improve the ability to maintain access to the cryptocurrency address while still maintaining robust security.

To prevent the conditional lower quorum from going into effect, the CMS **104** may monitor how much time has passed since the most recent transaction and may determine if the lower quorum should be allowed to go into effect or not. If the CMS **104** determines that the lower quorum should not be allowed to go into effect, the CMS **104** may initiate a new transaction—transferring the funds from the cryptocurrency address back to itself—resetting the time-based limitation to begin from the new transaction date.

As another example, there could also be a fourth authenticating key share (in addition to the primary three distributed to the CMD **103**, the CMS **104**, and the MCD **105**). In some embodiments the locking script in the most recent transaction involving the cryptocurrency address may specify that, in addition to being satisfied by two signatures produced by any two of the three private keys distributed to the CMD **103**, the CMS **104**, and the MCD **105**, the locking script may also, conditional on the current time being a specified amount of time from the transaction's submission date or after a particular time in the future, be satisfied by any two signatures produced by any two of the fourth authenticating key and the three private keys distributed to the CMD **103**, the CMS **104**, and the MCD **105**. In this case, the fourth private key is essentially inactive until the specified amount of time has passed, after which it automatically becomes active.

The fourth authenticating key share may, in general, be located on a variety of devices of systems. One example is that the fourth authenticating key share is also held by the CMS **104**. This may be particularly useful because the CMS **104**, as a typically larger distributed network, is less likely to suffer catastrophic failure. By making the fourth authenticating key share conditionally active, this enables a user to gain the reliability of storing the authenticating key shares necessary (e.g., for a quorum of 2) to access the cryptocurrency address **107** with a commercial operator without having to yield immediate control over their cryptocurrency funds to the operator.

Similar to the previous example, to prevent the fourth authenticating key from becoming active, the CMS **104** may monitor how much time has passed since the most recent transaction and may determine if the fourth authenticating key should be allowed to activate or not. If the CMS **104** determines that the fourth authenticating key should not be allowed to activate, the CMS **104** may initiate a new transaction—transferring the funds from the cryptocurrency address back to itself—resetting the time-based limitation to begin from the new transaction date.

One way that the conditional change to the quorum number may be implemented is using time-based condition requirements in the locking script of the transaction. For example, if the cryptocurrency involved is Bitcoin, the CHECKLOCKTIMEVERIFY command may be used to make parts of the locking script conditional on the passage of a certain amount of time. Thus, to implement a change in the quorum condition—say based on a lack of activity for 30 days—the locking script may be structured such that it is satisfied by either the production of a certain number of authenticating hashes (the usual quorum number) or by, after the passage of time specified by CHECKLOCKTIMEVERIFY, the production of one (or other number) less number of authenticating hashes. Whenever activity involving the cryptocurrency address **107** occurs (before the specified passage of time), the cryptocurrency management system **102** may refresh the timer by generating a new transaction with the cryptocurrency funds with the CHECKLOCKTIMEVERIFY changed to be 30 days from the time of the new transaction.

In some embodiments, rather than use a multi-signature cryptocurrency address, a single-signature cryptocurrency address may be used. To generate the authenticating key shares for the single-signature cryptocurrency address that are used to distribute control over the cryptocurrency address, a threshold secret sharing method may be used to divide information about the private key from the sole public-private key pair associated with the cryptocurrency address into a number of authenticating key shares. The nature of the generated authenticating key shares is such that possession of at least a threshold-amount of the key shares is sufficient to fully generate the private-key for the cryptocurrency address while any amount of key shares less than the threshold-amount provides no information about the private key.

For example, one threshold secret-sharing method that may be used to generate the authenticating key shares is flexible round-optimized Schnorr threshold signatures (FROST). At a high-level, the FROST method of key share generation takes place in two rounds. In the first round, each participant (i.e., the devices that will be getting one of the key shares), generate several random coefficients to a degree $m-1$ polynomial, where m is the threshold number of key shares needed to generate an authorizing signature. Each device then generates a commitment vector using these random coefficients and a generator point and uses the coefficient of the first entry as a private key to compute a Schnorr signature of the generated commitment vector. Each device then sends its commitment vector and compute Schnorr signature to every other device.

In the second round, each device generates a sub-share using the values from their commitment vector—one value for each share generated, which is for every participant—and sends a unique sub-share to every other device, keeping one sub-share for itself. Each device can then use the sub-shares they received from every other device (along with the sub-share the device generated and retained for itself) to generate a share key for that device.

FIG. **6** is a block diagram of a cryptocurrency management device (CMD) **103**, such as the CMD of FIG. **1**. As shown by the figure, a cryptocurrency management device (CMD) **103** may comprise at least one processor **603** that is connected to a communication interface **604** and a memory **605**. In general, the processor **603** may interact and control these components, as well as other components of the CMD **103**, to orchestrate the functioning of the device. The communication interface **604** may comprise circuitry that is configured to communicate with other devices over various communication channels.

For example, in some embodiments the communication interface **604** may allow communications over only a short-range, peer-to-peer communication channel (e.g., Bluetooth, Near Field Communication (NFC), or radio frequency identification (RFID)). Alternatively, in some embodiments the communication interface **604** may only networks such as the internet. As an example, the communication interface **604** may comprise modems, wireless radios (e.g., cellular transceivers), or other devices that are designed to wirelessly communicate with other devices or with network access points, such as cellular towers, network routers, Wi-Fi hots spots, or other types of access points. In general and as is relevant here, the communication interface **604** may be used to communicate with components of the cryptocurrency management system **102**—such as the CMS **104** and the MCD **105**—as well as with (particular nodes of) the cryptocurrency network **203**.

The memory **605** is connected to and editable by the processor **603**. The memory **605** may store, among other things, a cryptocurrency account (CA) private key share **108** and control logic **109**. As described further below, the CA private key share **108** is a cryptographic key associated with the private key of the public-private key pair (the private key of one of the public-private key pairs, for multi-signature addresses) of a cryptocurrency address (e.g., cryptocurrency address **107**). As also described further below, the control logic **109** may contain instructions that can be executed by the processor **603** to perform various functions of the CMD **103** described herein, including the initiation of or processing for a transaction involving the cryptocurrency address **107**.

In operation, the processor **603** may execute the instructions of the control logic **109** to manage the cryptocurrency assets associated with the cryptocurrency address **107**. This may involve communicating with the CMS **104** and the MCD **105** to obtain (or produce) authorizing signatures as well as communicating with (nodes of) the cryptocurrency network **203**. To obtain signatures from the CMS **104** or the MCD **105**, the processor **603** may interact with the communication interface **604** to communicate with the CMS **104** and the MCD **105**.

Note that the control logic **109** can be implemented in software, hardware, firmware or any combination thereof. In the exemplary CMD **103** illustrated by FIG. **6**, the control logic **109** is implemented in software and stored in the memory **605**. When implemented in software, the control logic **109** can be stored and transported on any computer-readable medium for use by or in connection with an instruction execution apparatus that can fetch and execute instructions, such as the processor **603**. In the context of this document, a "computer-readable medium" can be any means that can contain or store a computer program for use by or in connection with an instruction execution apparatus.

In some embodiments the CMD **103** may have a biometric sensor **608** for authenticating an authorized user. For example, in some embodiments the biometric sensor **608** is a fingerprint sensor located on a surface of the CMD **103**, but other types of biometric sensors **608** are possible in other examples. Other embodiments may not have a biometric sensor.

Note that, in some embodiments the CMD **103** may not have access the internet or some other form of wireless network. Rather, in some embodiments the CMD **103** may communicate only via short-range communication channels, requiring any devices seeking to interact with the CMD **103**, such as the MCD **105**, to be brought into close physical proximity (e.g., within several feet) to the CMD **103**. Limiting the range of the CMD **103** helps to enhance security by preventing at least some attempts by unauthorized user to access the data stored in the CMD **103**. Indeed, the CMD **103** may be kept for extended times in a secure location inaccessible to many hackers. When communication with the CMD **103** is desired, such as for authorization of a transaction involving the cryptocurrency managed by the CMD **103**, the MCD **105** may be taken to the CMD **103**.

In some embodiments, the CMD **103** may have a small, tag-like form factor that, among other things, allows the CMD **103** to be easily portable. When the CMD **103** is portable, it may be taken to a location associated with a transaction, such a location of a sale of product or service to be purchased by the cryptocurrency so that it is unnecessary to bring the MCD **105** to the secure location (e.g., home of the user) where the CMD **103** is normally kept. In other embodiments, the CMD **103** may have a larger, less portable form factor.

FIG. **7** is a block diagram of a cryptocurrency management server (CMS) **104**, such as the CMS of FIG. **1**. As shown by the figure, a cryptocurrency management server (CMS) **104** may comprise at least one processor **703** that is connected to a network interface **704** and a memory **705**. In general, the processor **703** may interact and control these components, as well as other components of the CMS **104**, to orchestrate the functioning of the device. The network interface **704** may comprise circuitry configured to communicate with other devices over various networks, such as the internet. As an example, the network interface **704** may comprise modems, wireless radios (e.g., cellular transceivers), or other devices that are designed to communicate with network access points, such as cellular towers, network routers, Wi-Fi hots spots, or other types of access points. In general and as is relevant here, the network interface **704** may be used to communicate with components of the cryptocurrency management system **102**—such as the CMD **103** and the MCD **105**—as well as with (particular nodes of) the cryptocurrency network **203**).

The memory **705** is connected to and editable by the processor **703**. The memory **705** may store, among other things, a cryptocurrency account (CA) private key share **110** and control logic **111**. As described further below, the CA private key share **110** is a cryptographic key associated with the private key of the public-private key pair (the private key of one of the public-private key pairs, for multi-signature addresses) of a cryptocurrency address (e.g., cryptocurrency address **107**). As also described further below, the control logic **111** may contain instructions that can be executed by the processor **703** to perform various functions of the CMS **104** described herein, including the initiation of or processing for a transaction involving the cryptocurrency address **107**.

In operation, the processor **703** may execute the instructions of the control logic **111** to manage the cryptocurrency assets associated with the cryptocurrency address **107**. This may involve communicating with the CMD **103** and the MCD **105** to obtain (or produce) authorizing signatures as well as communicating with (nodes of) the cryptocurrency network **203**. To obtain signatures from the CMD **103** or the MCD **105**, the processor **703** may interact with the network interface **704** to communicate with the CMD **103** and the MCD **105**.

Note that the control logic **111** can be implemented in software, hardware, firmware or any combination thereof. In the exemplary CMS **104** illustrated by FIG. **7**, the control logic **111** is implemented in software and stored in the memory **705**. When implemented in software, the control logic **111** can be stored and transported on any computer-readable medium for use by or in connection with an instruction execution apparatus that can fetch and execute instructions, such as the processor **703**.

FIG. **8** is a block diagram of a MCD **105**, such as the MCD **105** of FIG. **1**. The MCD **105** may be implemented as a smartphone, but other types of MCDs **105** are possible, such as a laptop or smart tag (e.g., a wearable device) for example.

As shown by the figure, an MCD **105** may comprise at least one processor **803** that is connected to a network interface **804**, and a memory **805**. In general, the processor **803** may interact and control these components, as well as other components of the MCD **105**, to orchestrate the functioning of the device. The network interface **804** may comprise circuitry configured to communicate with other devices over various networks, such as the internet. As an example, the network interface **804** may comprise modems, wireless radios (e.g., cellular transceivers), or other devices that are designed to communicate with network access points, such as cellular towers, network routers, Wi-Fi hots spots, or other types of access points. In general and as is relevant here, the network interface **804** may be used to communicate with components of the cryptocurrency management system **102**—such as the CMD **103** and the CMS **104**—as well as with (particular nodes of) the cryptocurrency network **203**). Any of the components of the cryptocurrency management system **102**, including the MCD **104**, may include other types interfaces, such as a short-range communication interface as described below with reference to the MCD **1402** depicted by FIG. **14**B.

The memory **805** is connected to and editable by the processor **803**. The memory **805** may store, among other things, a cryptocurrency account (CA) private key share **112** and control logic **113**. As described further below, the CA private key share **112** is a cryptographic key associated with the private key of the public-private key pair (the private key of one of the public-private key pairs, for multi-signature addresses) of a cryptocurrency address (e.g., cryptocurrency address **107**). As also described further below, the control logic **113** may contain instructions that can be executed by the processor **803** to perform various functions of the MCD **105** described herein, including the initiation of or processing for a transaction involving the cryptocurrency address **107**.

In operation, the processor **803** may execute the instructions of the control logic **113** to manage the cryptocurrency assets associated with the cryptocurrency address **107**. This may involve communicating with the CMD **103** and CMS **104** to obtain (or produce) authorizing signatures as well as communicating with (nodes of) the cryptocurrency network **203**. To obtain signatures from the CMD **103** or CMS **104**, the processor **803** may interact with the network interface **804** to communicate with the CMD **103** and CMS **104**.

Note that the control logic **113** can be implemented in software, hardware, firmware or any combination thereof. In the exemplary MCD **105** illustrated by FIG. **8**, the control logic **113** is implemented in software and stored in the memory **805**. When implemented in software, the control logic **113** can be stored and transported on any computer-readable medium for use by or in connection with an instruction execution apparatus that can fetch and execute instructions, such as the processor **803**.

Relatedly, in some embodiments the control logic **113** may be part of a software application running on the MCD **105**. For example, the control logic **113** may be part of a software application ("app") of a financial service provider.

In some embodiments, the MCD **105** may also comprise an input device **808** and an output device **809**. Generally speaking, the output device **803** is configured to communicate information to a user through some mechanism, such as a digital display. The processor **803** may interact with the output device **803** to transmit data to the user. Conversely, the input device **808** is configured to receive input from the user of the MCD **105**. For example, the input device **808** may be a touch screen that is capable of receiving user input in the form of taps, gestures, and other physical interactions with the screen. As indicated by this example, the input device **808** and the output device **809** may, in some embodiments, comprise the same device (e.g., a touchscreen display). Additionally, in some embodiments, either or both of the input device **808** and the output device **809** may comprise more than one physical device.

FIG. **9** is an illustration of an exemplary MCD having a digital screen as just described. Specifically, the MCD **902** of FIG. **9** (also referred to as the smartphone **902**) is implemented as a smartphone having a touch screen **905** on one side of the device (i.e., device front **903**) and a camera **906** on the opposite side (i.e., device back **904**). The touch screen **905** covers much of the device's front side **903** and implements both the input device **808** and the output device **809** of FIG. **8**. The touch screen **905** is capable of giving output by displaying images and video. The touch screen **905** is also capable of receiving user input in the form of taps, gestures, and other physical interactions with the screen. Not shown are the processor and memory internal to the MCD **902** but which function similarly to the processor **803** and the memory **805** of FIG. **8**.

As also shown by the figure, the MCD **902** may wirelessly communicate with various devices and access points. In particular, the MCD **902** may communicate directly (and wirelessly) with the CMD **103** using a short-range communication protocol, such as Bluetooth or NFC. The MCD **902** may also communicate indirectly with the CMS **104** through a network **907**. The MCD **902** may communicate with the network **907** through various communication protocols, such as a wireless broadband technology like long-term evolution (LTE) or a wireless network protocol like Wi-Fi. The network **907** may comprise multiple networks, including the internet and the internal network of various mobile providers.

FIG. **10** is a flowchart of an exemplary method of configuring a cryptocurrency management system **102** to begin managing cryptocurrency assets, such as previously described in the first step of FIG. **5**. To start, as shown by the figure, a security policy for the cryptocurrency management system **102** is chosen. Typically, though not necessarily, the security policy is set by a user to conform to the user's desired balance between security, reliability, and control. In particular, the user may determine what devices will be given an authenticating key share for the cryptocurrency address **107** and how many authenticating signatures may be required to approve a transaction. The cryptocurrency management system **102** may default to (and may even require) that CMD **103**, CMS **104**, and the MCD **105** be given authenticating key share. The cryptocurrency management system **102** may also default to having any two signatures generated by (different) authenticating key share be sufficient to authorize a transaction.

How the devices of the cryptocurrency management system **102** carry out this process may vary. In some embodiments, the configuration of the security policy by the user may be carried out on the MCD **105**. In some embodiments, the configuration may be carried out through the CMS **104**, such as by a user interacting with the CMS **104** through an online portal.

After the security policy is established, as shown by the next step of FIG. **10**, the cryptographic keys used to control the cryptocurrency address **107** (i.e., the authenticating key shares) may be generated. For a security policy involving the CMD **103**, CMS **104**, and the MCD **105**, as has been the case in previous examples, at least three authenticating key shares are generated. In general, the authenticating key shares are associated with (i.e., may be used in some manner to derive) the private key of the public-private key pair (or the private keys of the public private key pairs, for multi-signature addresses) that defines a cryptocurrency address.

Like in the previous step, how the devices of the cryptocurrency management system **102** carry out generating and distributing the authenticating key shares may vary. In some embodiments, the process may be handled by one centrally coordinating device (e.g., by the device the user specified the security policy on). In other words, in some embodiments the MCD **105** may generate the authenticating key shares and distribute one of these key shares to each of the CMD **103** and the CMS **104**. In other embodiments, the CMS **104** may generate the authenticating key shares and distribute one of these key shares to each of the CMS **104** and the MCD **105**. In yet other embodiments, the CMD **103**, CMS **104**, and the MCD **105** may mutually cooperate to generate the authenticating key shares. A benefit of this latter approach is that it can be performed in a way that does not allow any device to obtain or otherwise have access to any authenticating key shares other than the one it generates for itself.

Next, a cryptocurrency address corresponding to the public key of the public-private key pair used to generate the authenticating key shares and the chosen security policy is created by having a transaction generate an output tuple with a locking script requiring a certain number of signatures generated using authenticating key shares. Like with the previous two steps, which device actually generates and submits the initial cryptocurrency address creating transaction to the cryptocurrency network may vary. In some embodiments, the MCD **105** may submit the initial transaction to the cryptocurrency network. In other embodiments, the CMS **104** may submit the initial transaction.

FIG. **11** is a flowchart of an exemplary method of a cryptocurrency management system **102** initiating and authenticating a cryptocurrency transaction. To start, a user initiates a financial transaction involving the cryptocurrency address **107**. As an example, the financial transaction may be initiated via a mobile wallet application executing on the MCD **105**. In particular initiating the financial transaction may involve a user opening the mobile wallet application and entering details about a transaction, such as the amount to be transferred. The user may then provide some form of authentication such as a password or fingerprint, to authenticate approve the entered transaction. If the MCD **105** accepts the user's provided authentication, it may initiate the transaction.

After the financial transaction is initiated, the MCD may then begin the process of authenticating the transaction. To this end, the MCD **105** generates a first authenticating signature for the transaction. The MCD **105** may also work to obtain the remaining information (e.g., the signatures) needed to authorize the transaction from the other components of the cryptocurrency management system **102**. Specifically, the MCD **105** may communicate with either the CMD **103** or the CMS **104** to obtain a second authenticating signature for the transaction.

In some embodiments, the MCD **105** may preferentially select the CMS **104** as the source of the second authenticating signature. The rationale for this preference is that the CMS **104** is likely to be simpler and more readily available than the CMD **103**. This may be especially true for embodiments where access to the CMD **103**—or at least access to the CMD's ability to generate the second authenticating signature—is limited to share-range communications.

If the MCD **105** is communicating the CMD **103** to obtain the second authenticating signature, the MCD **105** may first initiate communications with the CMD **103**. After initiating communications with the CMD **103**, the MCD **105** may provide information to the CMD **103** indicating the transaction is authorized. More precisely, the MCD **105** may provide information authenticating the identity of the MCD **105** to the CMD **103**. The MCD **105** may also provide the proposed transaction, which may be used by the CMD **103** to generate the second authenticating signature.

After receiving the request and validating information from the MCD **105**, the CMD **103** may evaluate the information to confirm the identity of the MCD **105**. For example, the CMD **103** and the MCD **105** may each have a public-private key pair used for identification and may have each previously (securely) communicated the public key from the public-private key pair to each other. The MCD **105** may sign its message with its private key, allowing the CMD **103** to determine—using the previously transferred public key from the MCD **105**—that the message originates from the MCD **105**.

If the CMD **103** successfully authenticates the MCD **105**, the CMD **103** may then determine whether to accept the request from the MCD **105** and generate the requested authenticating signature. If the CMD **103** accepts the request, the CMD **103** may generate the requested second authenticating signature and transmit the second authenticating signature to the MCD **105**.

A variety of factors may affect whether the CMD **103** accepts the request from the MCD **105**. For instance, if the CMS **104** fails to successfully authenticate the MCD **105**, it may deny the request. As another example, the CMD **103** may require that the request (and subsequent transfer of a second authenticating signature) be conducted only over a short-range communication channel. The CMD **103** may also require that a user provide their fingerprint to the CMD **103** for a transaction to be approved.

In the event the CMD **103** rejects the request, the CMD **103** may respond in a variety of ways, depending on the reasons for the rejection. For example, the CMD **103** may communicate with the MCD **105** to indicate the reason the request was rejected. In particular, the CMD **103** may indicate to the MCD **105** if the CMD **103** was unable to authenticate the MCD **105** or may indicate that the authentication was successful but one or more of the CMD's requirements to authorize a transaction was not met (e.g., that the user did not supply a correct fingerprint with the required timeframe).

In response to a request rejection, the MCD **105** may take several actions, also possibly depending on the reason for the rejection. For example, if the MCD **105** determines that the reason for the rejection can be remedied, it may perform the correction and send a new request to the CMD **103**. As an example of such a correction, if the CMD **103** indicates that the request was rejected because the user did not supply his or her fingerprint in time, the MCD **105** may prompt the user to provide his or her fingerprint to the CMD **103** and, upon receiving acknowledgement from the user, send a new request for the second authenticating signature to the CMD **103**.

If the MCD **104** is unable to remedy the reason for rejection—either because of the reason for the rejection or because too many retried requests have been sequentially rejected—the MCD **105** may indicate to the user that authenticating the transaction has failed. This indication may also include information about the reason for the failure. Additionally, the MCD **105** may also, if it has not done so already, attempt to obtain the second authenticating signature from the CMS **104**.

Alternatively, if the MCD **105** is communicating with the CMS **104** to obtain the second authenticating signature, the MCD **105** may first initiate communications with the CMS **104**. After initiating communications with the CMS **104**, the MCD **105** may provide information to the CMS **104** indicating the transaction is authorized. More precisely, the MCD **105** may provide information authenticating the identity of the MCD **105** to the CMS **104**. The MCD **105** may also provide the proposed transaction, which may be used by the CMS **104** to generate the second authenticating signature.

After receiving the request and validating information from the MCD **105**, the CMS **104** may evaluate the information to confirm the identity of the MCD **105**. For example, the CMS **104** and the MCD **105** may each have a public-private key pair used for identification and may have each previously (securely) communicated the public key from the public-private key pair to each other. The MCD **105** may sign its message with its private key, allowing the CMS **104** to determine—using the previously transferred public key from the MCD **105**—that the message originates from the MCD **105**.

If the CMD **103** successfully authenticates the MCD **105**, the CMD **103** may then determine whether to accept the request from the MCD **105** and generate the requested authenticating signature. If the CMS **104** accepts the request, the CMD **103** may generate the requested second authenticating signature and transmit the second authenticating signature to the MCD **105**.

A variety of factors may affect whether the CMS **104** accepts the request from the MCD **105**. For instance, if the CMS **104** fails to successfully authenticate the MCD **105**, it may deny the request. As another example, the CMS **104** may examine the contents of the proposed transaction and determine if the transaction complies with a transaction policy for the cryptocurrency address **107**. For example, the transaction policy may indicate that the server will only approve transactions under a certain value or that the server will not approve any transactions that result in exceeding a maximum spending limit from some set time period, such as per day, per week, or per month. The contents of the policy may be set by the user or may be a default policy enforced by the CMS **104** for security reasons. Typically, though not necessarily, to approve a transaction that violates the transaction policy of the CMS **104**, the CMD **103** is used to provide the second authenticating signature.

In the event the CMS **104** rejects the request, the CMS **104** may respond in a variety of ways, depending on the reasons for the rejection. For example, the CMS **104** may communicate with the MCD **105** to indicate the reason the request was rejected. In particular, the CMS **104** may indicate to the MCD **105** if the CMS **104** was unable to authenticate the MCD **105** or may indicate that the authentication was successful but one or more of the CMD's requirements to authorize a transaction was not met (e.g., the proposed transaction does not comply with the CMS's transaction policy for the cryptocurrency address **107**).

In response to a request rejection, the MCD **105** may take several actions, also possibly depending on the reason for the rejection. For example, if the MCD **105** determines that the reason for the rejection can be remedied, it may perform the correction and send a new request to the CMS **104**.

If the MCD **105** is unable to remedy the reason for rejection—either because of the reason for the rejection or because too many retried requests have been sequentially rejected—the MCD **105** may indicate to the user that authenticating the transaction has failed. This indication may also include information about the reason for the failure. Additionally, the MCD **105** may also, if it has not done so already, attempt to authenticate obtain the second authenticating signature from the CMD **103**. If the CMD **103** requires that requests for it to generate a second authenticating signature be conducted only over a short-range communication protocol, the MCD **105** may prompt the user to retrieve the CMD **103** (or bring the MCD **105** into close physical proximity to it) and, when the user confirms the CMD **103** is nearby, may request a second authorizing signature for the proposed transaction, as previously described.

Eventually, the MCD **105** may obtain the second and third authenticating signatures from the CMD **103** and the CMS **104**. After they are received, the MCD **105** may combine them with the first authenticating signature to generate a fully authenticated cryptocurrency transaction. Specifically, the MCD **105** may obtain the second and third authenticating signatures and, after they are obtained, use the second and third authenticating signatures, along with the first authenticating signature, to generate a fully authenticated cryptocurrency transaction.

Note that the method described here is performed with the MCD **105** as the initiator of the transaction. However, as noted above, either of the CMD **103** or the CMS **104** may alternatively initiate the transaction. In such a case, the initiating device or system may perform the same or similar steps performed by the MCD **105**.

In some embodiments, the cryptocurrency management system **102** may comprise multiple MCDs, each with their own private key share. As a consequence of having multiple MCDs, there may be more than three private key shares spread across the devices comprising the cryptocurrency management system **102**. For example, in an embodiment where there are two MCDs, there may be four private key shares: one private key share at the CMD **103**, one private key share at the CMS **104**, one private key share at the first MCD **105**, and one private key share at the second MCD **105**. When there are multiple MCDs present, the threshold requirements (i.e., what signatures are necessary) to authorize a transaction involving the cryptocurrency address **107** may vary. For example, in some embodiments any two signatures produced from any two private key shares—including the two private keys associated with two MCDs—may be sufficient to authorize a transaction. In some embodiments the signature from either the CMD **103** or the CMS **104**—along with at least one signature from any other device—may be required to authorize a transaction.

In some embodiments having multiple MCDs **105**, each MCD **105** may be associated with a different user. For example, in a family of 3, such as a husband, wife, and their son, the cryptocurrency management system **102** may comprise three MCDs: one for the husband, one for the wife, and one for the son. Note that the relationship between the different users need not be familial. For example, in some embodiments the multiple users may be officers of a corporation.

In some embodiments having multiple MCDs **105**, the limitations of the transaction policy enforced by the CMS **104** may differ depending on which MCD (more precisely, on which MCD's private key share) is used to generate a signature. For example, in an embodiment comprised of two MCDs **105**, the transaction policy with respect to the first MCD **105** may have a higher spending limit than with respect to the second MCD **105**. This may be a useful mechanism to enforce different limitations based on the identity of the user which, in many circumstances, has a one-to-one correspondence with a particular MCD **105**. For instance, take the previous example where a father, mother, and son each have an MCD **105**. The transaction policy may be that the father and mother's MCDs may be used to authorize transactions up to $100 dollars while the son's MCD may be use only to authorize transactions up to $20 dollars. Other embodiments may have different transaction policy variations based on the stored private key share's owner.

Various means may be employed to enforce different transaction policy limitations based on the identity of the MCD **105** (more precisely, the identity of the MCD's CA private key share **110**) whose signature is being used to authorize the transaction. For example, in some embodiments a signature from the CMS **104** may be required to authorize any transaction (except, possibly, for transactions including the signature from the CMD **103**), no matter how many other signatures from other devices are included. This may allow the CMS **104** to always assess a transaction for compliance with its transaction policy and to refuse to provide a signature for proposed transactions that violate the transaction policy, requiring either the use of a different MCD **105** or, possibly, the use of the CMD **103** to authorize the transaction. Alternatively, in some embodiments the transaction policy may only be enforced if the CMS **104** is used as the source of the second authenticating signature and other MCDs **105** may be able to provide a second authenticating signature sufficient to fully authorize the proposed transaction, even if the proposed transaction violates the transaction policy of the CMS **104**.

Note that, if multiple MCDs **105** contribute their signature to a proposed transaction and—for some reason—request an additional signature from the CMS **104**, the CMS **104** may apply any one of the device's transaction policy limitations when determining whether to provide the CMS's authenticating signature. For example, in some embodiments the CMS **104** may choose the transaction policy of the device (whose signature is present in the request) that has the broadest (i.e., least restrictive) limitations. In some embodiments, the CMS **104** may choose the transaction policy of the device that has the narrowest (i.e., most restrictive) limitations. In other embodiments, the CMS **104** may employ different criteria in selecting which transaction policy limitations to apply to a multiple-MCD authentication request.

FIG. **12** is a flowchart of an exemplary method of finalizing an authenticated cryptocurrency transaction with a cryptocurrency network **106**, such as the cryptocurrency network of FIG. **1**. To start, as shown by the figure, the MCD **105** obtains the quorum of signatures needed to satisfy the locking script associated with the cryptocurrency address. After the MCD **105** obtains the quorum of signatures, the MCD **105** may use the quorum of authenticating signatures to generate a fully authenticated cryptocurrency transaction, and as shown by the next step, the MCD **105** may transmit the fully authenticated cryptocurrency transaction to one or more cryptocurrency nodes **204** in the cryptocurrency network **203** that is associated with the cryptocurrency address.

After they receive the fully authenticated cryptocurrency transaction, the cryptocurrency nodes **203** may verify the fully authenticated cryptocurrency transaction and, after having verified the transaction, add the fully authenticated cryptocurrency transaction to the pool of pending transactions. Eventually, one of the cryptocurrency nodes **204** successfully produces a new block **303** including the fully authenticated cryptocurrency transaction. After this new block is produced and distributed to the other cryptocurrency nodes **204** in the cryptocurrency network **203**, the cryptocurrency transaction is effectively finalized.

Generally, the cryptocurrency management system **102** is associated with a security policy (with respect to a given cryptocurrency address **107**). The security policy, among other things, details the requirements for controlling the cryptocurrency address **107**. As an example, this involves the security policy specifying the number of authenticating key shares and the number of them (referred to as the quorum) that is required to approve a financial transaction involving the cryptocurrency address (specifically, the number of authenticating signatures generated from the authenticating key shares).

Note that, with regards to the cryptocurrency network **203**, the requirements to use the cryptocurrency assets associated with the cryptocurrency address **107** are controlled by the locking scripts of the transactions associated with the cryptocurrency address **107**. Thus, to effectuate the security policy associated with the cryptocurrency management system **102** (and to effect changes to the security policy), a first step may be to generate a transaction using the funds associated with the cryptocurrency address **107** as both input and output, with the output specifying a locking condition in accordance with the cryptocurrency management system's associated security policy. Thus, part of the process of configuring the cryptocurrency management system **102** is setting-up the cryptocurrency address **107** so that it conforms to this security policy.

FIG. **13** is a flowchart of an exemplary method of modifying the security policy of a cryptocurrency management system **102**. To start, an updated security policy for the cryptocurrency management system **102** is chosen, and as shown by the next step, at least three new authenticating key shares are generated using (one or more private keys of) one or more newly generated public-private key pairs. In addition, a new cryptocurrency address corresponding to the newly generated one or more public-private key pairs and the updated security policy is created by creating a transaction transferring the cryptocurrency assets from the previous cryptocurrency address with an output tuple with a locking script requiring a certain number of signatures generated by the newly generated public keys' corresponding private keys. After the new cryptocurrency address is created, the CMD **103**, the CMS **104**, and the MCD **105** are each uniquely assigned and sent one of the authenticating key shares corresponding to the private keys of the one or more new public-private key pairs.

Note that the security policy may involve more detailed requirements than just the quorum of authenticating signatures for authenticating a transaction. For example, in some

embodiments, the security policy may make the quorum conditional on the occurrence of certain events. One such event may be the passage of a certain amount of time without any user initiated activity with the cryptocurrency address **107**. If this occurs, the quorum can be reduced (e.g., from three authenticating signatures to two authenticating signatures) or otherwise changed. This may be useful in preventing loss of access to the cryptocurrency address due to the loss or failure of one of the CMD **103**, the CMS **104**, or the MCD **105**. By automatically reducing the quorum when there is no user-initiated activity (as might be the case when a user could not conduct any activity because of a missing or failed device), this may improve the ability to maintain access to the cryptocurrency address while still maintaining robust security.

One way that the conditional change to the quorum number may be implemented is using time-based condition requirements in the locking script of the transaction. For example, if the cryptocurrency involved is Bitcoin, the CHECKLOCKTIMEVERIFY command may be used to make parts of the locking script conditional on the passage of a certain amount of time. Thus, to implement a change in the quorum condition—say based on a lack of activity for 30 days—the locking script may be structured such that it is satisfied by either the production of a certain number of authenticating hashes (the usual quorum number) or by, after the passage of time specified by CHECKLOCKTIMEVERIFY, the production of one (or other number) less number of authenticating hashes. Whenever activity involving the cryptocurrency address **107** occurs (before the specified passage of time), the cryptocurrency management system **102** may refresh the timer by generating a new transaction with the cryptocurrency funds with the CHECKLOCKTIMEVERIFY changed to be 30 days from the time of the new transaction.

As another example, there could also be a fourth authenticating key share (in addition to the primary three distributed to the CMD **103**, the CMS **104**, and the MCD **105**). The security policy may generally be that this fourth authenticating key share is inactive and that inactive key shares (and their corresponding signatures) do not contribute to obtaining the needed quorum. However, the security policy could also be that the fourth authenticating key share may become active on the occurrence of a certain event. One such event may be the passage of a certain amount of time without any activity or certain activities involving the cryptocurrency address. If this occurs, the fourth authenticating key share can be activated. This may be useful in preventing loss of access to the cryptocurrency address due to the loss or failure of one of the CMD **103**, the CMS **104**, or the MCD **105**. By automatically enabling another authenticating key share when there is no activity (such as might occur when a user could not conduct any activity because of a missing or failed device), this may improve the ability to maintain access to the cryptocurrency address while still maintaining robust security.

The fourth authenticating key share may, in general, be located on a variety of devices of systems. One example is that the fourth authenticating key share is also held by the CMS **104**. This may be particularly useful because the CMS **104**, as a typically larger distributed network, is less likely to suffer catastrophic failure. By making the fourth authenticating key share conditionally active, this enables a user to gain the reliability of storing the authenticating key shares necessary (e.g., for a quorum of 2) to access the cryptocurrency address **107** with a commercial operator without having to yield immediate control over their cryptocurrency funds to the operator.

As previously mentioned, for consumers, many financial transactions involve the consumer exchanging some form of currency with a seller for some kind of good or service in exchange). In today's world, this exchange of currency is increasingly done via electronic systems that, at some point, involve communication via a network, such as the internet. Contributing to this increase is that financial transactions are increasingly conducted using payment cards (e.g., debit cards or credit cards) and mobile payment services as opposed to physical cash or checks.

While electronic transfer of funds does provide advantages, particularly in the form of increased convenience, it also presents some drawbacks, such as being unable to conduct a transaction without an active internet or other type of network connection. While this may be an acceptable tradeoff in many circumstances, there are still many occasions where the requirement of an active internet connection is problematic. Despite its seeming ubiquity, there are still many occasions where internet service is unreliable or unavailable when users are looking to make a financial transactions. In such situations, a lack of internet connectivity can be a significant impediment to one or more parties seeking to engage in a financial transaction.

Moreover, to the extent that methods exist that do not rely on internet connectivity, such as physical currency, they do not solve this problem. In this regard, such methods may be either (or both) inconvenient or disfavored by either one or more parties in a financial transaction. In the case of the latter, this often leads to the method of payment not being available because either a party cannot or will not use or accept it. For many purchases or other types of fund transfers, convenience is often a strong factor in whether a party will actually initiate a financial transaction. Impediments to the transaction generally make it less likely to occur.

Take, for example, physical currency (e.g., paper money or coins). In theory, physical currency allows financial transactions to be settled locally (and anonymously) between a buyer and seller without needing any kind of active internet connection or communication with a third-party. However, relying on physical currency suffers from the problems identified above. For a variety of reasons, individuals are increasingly carrying less physical currency, meaning that, for a seller, attempting to rely on cash to conduct financial transactions, sales may be reduced.

Of course, a seller could, in theory, "accept" a payment using a payment card even without an active internet connection. Specifically, a seller could "accept" payment by recording the relevant information (e.g., credit card number and the agreed upon amount of payment) and then later using that recorded information to actually effect the transaction with the relevant third-party (the credit card issuer) when an active internet connection is available. However, this presents a substantial significant risk of fraud. The risk of fraud is even greater for many of the events where there is a lack of a reliable internet connection, because their nature is often to be one-off exchanges. In other words, many of these exchanges are likely to occur where the buyer and seller are unknown to one another and are unlikely to easily encounter one another again. This means that finding the other party after the transaction is likely to be difficult if at all possible.

In addition, even when an internet connection is available, one party in a transaction may be reluctant to share with the other party certain information, such as an account number or other personal information required for an electronic transfer of funds. As an example, two parties may desire to split an expense, such as a taxi fee or dinner check, by transferring funds from one party to the other, but both parties may be reluctant to share personal information related to the transaction, such as an account of a financial account to be used in the transfer.

In some embodiments, one or more components of the cryptocurrency management system **1402**, such as the MCD **1405**, may utilize assets stored locally to settle financial transactions directly, without requiring a concurrent internet connection. Specifically, embodiments of the present disclosure may utilize a MCD **1405** to directly (i.e., in a peer-to-peer fashion) conduct and settle a financial transaction with another MCD. To accomplish this goal, each MCD (also referred to herein as "mobile device" for simplicity) may have a mobile wallet located within its non-volatile memory, which can be used to store financial assets (e.g., a digital currency, such as Bitcoin). At some point prior to their interaction, the MCD that is exchanging financial assets (e.g., that is being used to "pay") transfers financial assets into its mobile wallet from a financial service provider. Consequently, the MCD can then transfer these financial assets, or a portion of them, to the mobile wallet of the second MCD. After the transaction, the second MCD can then transfer these financial assets from its mobile wallet to a financial service provider or other entity as may be desired. Note that this may also be implemented on MCDs that are not part of a cryptocurrency management system **1402**.

FIG. **14**A is a block diagram of a financial system **2102** having MCDs **2105** and **2107** that are configured to perform a process of settling local peer-to-peer financial transactions as described above. The financial system **2102** may also comprise a first financial service provider system **2103** and a second financial service provider system **2109**. The financial service provider system **2103** may be associated with (e.g., managing) cryptocurrency assets **2104** owed by the user of MCD **2105**. Similarly, the financial service provider system **2109** may be associated with cryptocurrency assets **2110** owed by the user of MCD **2107**.

Broadly speaking, the MCDs **2105** and **2107** may directly communicate with one another to initiate and settle a financial transaction. Towards this end, prior to the transaction, the MCD **2105** may communicate with financial service provider system **2103** to obtain some or all of cryptocurrency assets **2104** in the form of cryptocurrency assets **2106**. The cryptocurrency assets **2106** may be used by the MCD **2105** in settling various financial transactions. In a somewhat mirrored process, after the financial transaction is settled and some or all of the cryptocurrency assets **2106** are received by the MCD **2107** as cryptocurrency assets **2108**, the MCD **2107** may communicate with its financial service provider system **2109** to transfer some or all of the cryptocurrency assets **2108** to the financial service provider system **2109**, where they are stored as cryptocurrency assets **2110**. In addition, the financial service provider systems **2103** and **2109** may communicate with one another for various reasons, such as for financial service provider system **2109** to inform financial service provider system **2103** that the transferred assets from MCD **2105** have been deposited.

FIG. **14**B is a simplified schematic illustrating an exemplary embodiment of an MCD **1402**, such as the MCD **2105** of FIG. **14**A. As shown by the figure, an MCD **1402** may comprise at least one processor **1403** that is connected to a network interface **1404**, a short-range communications interface **1405**, and a memory **1406**. In general, the processor **1403** may interact and control these components, as well as other components of the MCD **1402**, in order to orchestrate the functioning of the device. The network interface **1404** may comprise circuitry configured to communicate with other devices over various networks, such as the internet. As an example, the network interface **1404** may comprises modems, wireless radios (e.g., cellular transceivers), or other devices that are designed to communicate with network access points, such as cellular towers, network routers, Wi-Fi hots spots, or other types of access points. The short-range communications interface **1405** may comprise circuitry configured to communicate with other nearby devices using short-range peer-to-peer wireless connectivity. As an example, the short-range communications interface **1405** may comprise a wireless radio that is configured to communicate in accordance with an established short-range protocol, such as Bluetooth, Near Field Communication (NFC), or radio frequency identification (RFID). In some cases, such as when NFC is used, active or passive load modulation may be used for the short-range communication. In general and as is relevant here, the network interface **1404** may be used to communicate with various financial service providers and the short-range communications interface **1405** may be used to communicate with other nearby readers or other types of devices (e.g., smartphones).

The memory **1406** is connected to and editable by the processor **1403**. The memory **1406** may store, among other things, a mobile wallet **1407** and a mobile wallet logic **1408**. As described further below, the mobile wallet **1407** may be used to store data representing financial asserts. As also described further below, the mobile wallet logic **1408** may contain instructions that can be executed by the processor **1403** to perform various functions of the MCD **1402** described herein, including the transfer financial assets (e.g., between an account at a financial service provider and the mobile wallet **1407** or between the mobile wallet **1407** and the mobile wallet of another MCD).

In operation, the processor **1403** may execute the instructions of the mobile wallet logic **1408** to either transfer financial assets between a financial service provider and the mobile wallet **1407** or to transfer financial assets between the mobile wallet **1407** and the mobile wallet of another MCD. To transfer financial assets from a financial service provider to the mobile wallet **1407**, the processor **1403** may interact with the network interface **1404** to communicate with the financial service provider. Similarly, to transfer assets from the mobile wallet **1407** to the mobile wallet of another MCD, the processor **1403** may interact with the short-range communications interface **1405** to directly communicate with the other MCD.

Note that the mobile wallet logic **1408** can be implemented in software, hardware, firmware or any combination thereof. In the exemplary MCD **1402** illustrated by FIG. **14**B, the mobile wallet app **1408** is implemented in software and stored in the memory **1406**. When implemented in software, the mobile wallet app **1408** can be stored and transported on any computer-readable medium for use by or in connection with an instruction execution apparatus that can fetch and execute instructions, such as the processor **1403**. In some embodiments, the mobile wallet logic **1408** may be part of a software application running on the MCD **1402**. For example, the mobile wallet logic **1408** may be part of a software application ("app") of a financial service provider.

In some embodiments, the MCD **1402** may also comprise an input device **1409** and an output device **1410**. Generally speaking, the output device **1503** is configured to communicate information to a user through some mechanism, such as a digital display. The processor **1403** may interact with the output device **1503** to transmit data to the user. Conversely, the input device **1409** is configured to receive input from the user of the MCD **1402**. For example, the input device **1409** may be a touch screen that is capable of receiving user input in the form of taps, gestures, and other physical interactions with the screen. As indicated by this example, the input device **1409** and the output device **1410** may, in some embodiments, comprise the same device (e.g., a touchscreen display). Additionally, in some embodiments, either or both of the input device **1409** and the output device **1410** may comprise more than one physical device.

Similar to the MCD **105** of FIG. **8**, the MCD **1402** may be implemented as a smartphone, such as the smartphone depicted in FIG. **9**. Not shown are the processor and memory internal to the smartphone **902** but which function similarly to the processor **803** and the memory **805** of FIG. **8**.

FIG. **15** is a block diagram illustrating a more detailed view of the financial system **2102** shown in FIG. **14**A. As shown by the figure, the financial system **1502** may comprise MCDs **2105** and **2107** that are configured to perform a process of settling local peer-to-peer financial transactions as described above. Note that each of the MCDs **2105** and **2107** may be configured in accordance with the MCD **1402** depicted by FIG. **14**B. The financial system **2102** may also comprise the first financial service provider system **2103** and the second financial service provider system **2109**. The financial service provider system **2103** is associated with a first financial service provider **1517** and the MCD **2105**. Similarly, the financial service provider system **2109** is associated with a second financial service provider **1518** and the MCD **2107**.

Broadly speaking, the MCDs **2105** and **2107** may directly communicate with one another, over a communication channel **1514** (e.g. NFC, RFID, or Bluetooth), to initiate and settle a financial transaction. Towards this end, prior to the transaction, the MCD **2105** may communicate with financial service provider system **2103**, over a communication channel **1513** (e.g., via a network, such as the internet), to transfer financial assets (e.g., digital currency) onto the MCD **2105** that are then used in settling various financial transactions. In a somewhat mirrored process, after the financial transaction is settled, the MCD **2107** may communicate with its financial service provider **2109**, over communication a channel **1515** (e.g., via a network, such as the internet), to transfer financial assets it has received to the financial service provider system **2109**. In addition, the financial service provider systems **2103** and **2109** may communicate with one another over a communication channel **1516** for various reasons, such as for financial service provider system **2109** to inform financial service provider system **2103** that the transferred assets from MCD **2105** have been deposited.

More precisely, the MCDs **2105** and **2107** have associated local asset storages—asset storages **1506** and **1508**, respectively—that can be used by the MCDs **2105** and **2107** to store financial assets. For example, the local asset storages **1506** and **1508** may be used to store cryptocurrencies, such as Bitcoin or Ethereum. Each of these local asset storages is linked to a corresponding user account of a financial service provider. Thus, the local asset storage **1506** of the MCD **2105** is linked to a corresponding user account **1510** of the financial service provider **1517**, with the corresponding financial service provider system **2103** being able to interact with and control various aspects of the user account **1510**. Similarly, the local asset storage **1508** of the MCD **2107** is linked to a corresponding user account **1512** of the financial service provider **1518**, with the corresponding financial service provider system **2109** being able to interact with and control various aspects of the user account **1512**. Funds can be transferred between a user account and its linked local asset storage as well as between the local asset storages **1506** and **1508** of the MCDs **2105** and **2107**.

In general, the financial system **2102** may be divided into two groupings: local grouping **1503** and remote grouping **1504**. The local grouping **1503** comprises the MCDs **2105** and **2107** and the remote grouping **1504** comprises the financial service provider systems **2103** and **2109**. Interactions between devices in local grouping **1503** occur locally (e.g., the devices are close, such as within several meters or less of one another, and communicate directly using short-range communications) whereas interactions with devices in remote grouping **1504**, including interactions by a device in the remote grouping **1504** and a device in local grouping **1503** (e.g., MCDs **2105** and **2107**) occur remotely (e.g., the devices are distant from one another and communicate using long-range communications).

This distinction can be illustrated with reference to the communication channel **1513**, which, as previous mentioned, is used to transfer (i.e., load) funds onto the MCD **2105**. The MCD **2105** and the financial service provider system **2103** (e.g., one or more servers or other hardware supporting the financial service provider's online operations) may be remote from one another (e.g., at least several kilometers). Thus, to communicate with one another, the MCD **2105** and the financial service provider system **2103** may use a wide area network (WAN), such as the internet. Conversely, the communication channel **1514**, as previously mentioned, is used by two MCDs to conduct (e.g., initiate and settle) a financial transaction while in close physical proximity. Thus, to communicate with one another, the MCDs **2105** and **2107** use a direct (i.e., peer-to-peer) connection using some type of short-range communication protocol, such as NFC, RFID, or Bluetooth.

FIG. **16** is a flowchart illustrating a process of locally conducting a financial transaction between the MCDs **2105** and **2107** and the financial service provider systems **2103** and **2109** of FIG. **15**. Briefly, the process involves (1) preemptively transferring financial assets from financial service provider system **2103** onto the MCD **2105**, (2) using the MCD **2105** to enter a financial transaction with the MCD **2107**, and (3) settling (e.g., paying for) the transaction using the locally stored funds.

To start, the process begins with the MCD **2105** communicating with the financial service provider system **2103** to acquire and transfer financial assets into the MCD's local asset storage **1506**. More precisely, the MCD **2105** communicates with the financial service provider system **2103** via communication channel **1513** using MCD's network interface **1404**. This exchange involves communicating over a network, such as the internet. In general, the purpose of this step is to locally store financial assets on the MCD **2105** that can be accessed and transferred to the MCD **2107** without needing to communicate with a third-party to effectuate the transfer.

Broadly speaking, the financial assets should be stored on the MCD **2105** in such a form that, like physical currency, their validity and authenticity can be verified by other parties in a transaction without needing to query a third-party over the internet. An example of a suitable digital financial asset is cryptocurrency.

Note that the financial assets may be transferred from a financial service provider. As discussed further below, having the financial assets taken from a financial service provider helps to avoid double-spend attacks. Since digital data can be endlessly copied, financial assets represented by digital data can be duplicated by a malicious actor and subsequently reused in later transactions. This problem is usually avoided by the party to whom a financial asset is being transferred (e.g., a seller) announcing to relevant third-parties that the financial asset has been transferred, as is done with cryptocurrency transactions. These third-parties then know not to accept the financial asset if it is being sent from the malicious actor. Who the relevant third-parties are may depend on the specific financial assets in question. In general, however, for a given specific financial asset, the identity of the relevant third-parties is usually public (and widely available) information.

For example, for cryptocurrencies, the relevant entities are the collective Bitcoin nodes. Pragmatically, however, alerting the nodes of the Bitcoin network can be done by alerting a few of the nodes that then facilitate propagating knowledge of the transaction to the other nodes in the Bitcoin network. A similar process can occur for other cryptocurrencies.

Unfortunately, without a reliable internet connection, this method can be unavailable, at least temporarily. This can be mitigated by having the transferred financial assets to be linked to the financial service provider (and to a specific account at the financial service provider). This information can be used, for example, to allow the financial service provider to guarantee against any double-spent financial assets (and then seek action against the fraudulent actor).

After the financial assets are transferred onto the asset storage **1506** of the MCD **2105**, the MCD **2105** can then be used to locally conduct and settle offline, peer-to-peer financial transactions with other MCDs (e.g., MCD **2107**). Accordingly, at some point after the financial assets are obtained, the MCD **2105** may be used to initiate a financial transaction with the MCD **2107**. More precisely, after the MCD **2105** stores the financial assets into its local storage **1506**, the MCD **2105** may initiate and finalize a financial transaction with the MCD **2107**. In particular, the MCD **2105** may communicate with the MCD **2107** via communication channel **1514** using the MCDs' respective short-range network interfaces **1405**. This exchange can involve directly communicating using peer-to-peer short-range wireless communication protocols, such as Bluetooth, Wi-Fi, near-field communication (NFC), Ultra-wideband (UWB), IEEE 1902.15.4, or RFID.

In general, a purpose of the second step of FIG. **16** is to actually create a financial transaction that needs to be settled. It is important to note here two related but distinct potential meanings of "financial transaction," largely revolving around interactions between the MCDs or interactions between the human users of the MCDs. In other words, the MCDs **2105** and **2107** are associated with and being operated by human users (e.g., a buyer and a seller). In many situations, it is likely that the buyer and seller verbally discuss and agree to a transaction, with the MCDs **2105** and **2107** being used to settle the transaction. The second use of "financial transaction" is the interactions between the MCDs **2105** and **2107** (and also between the users and their respective MCDs) that are used to formalize the transaction on the MCDs so that the stored financial assets can be used to settle the transaction (e.g., pay for goods being bought).

As an example and as will be discussed more thoroughly below, initiating a financial transaction using an MCD **2105** may involve the user (e.g., a seller) of the MCD **2107** using the MCD **2107** to send a request to open a transaction session with the MCD **2105**. The user of the MCD **2105** (e.g., a buyer) may accept this request, starting the transaction session and thus initiating a financial transaction. The seller could then send the details of the proposed transaction from their MCD **2107** to the buyer's MCD **2105**. The buyer could accept the proposed transaction, which would finalize it, making it ready to be settled. Notably, the details of the proposed financial transaction could have already been established by verbal discussion between the buyer and seller, with the interactions between the MCDs being to formalize the transaction such that the MCD **2105** could use stored financial assets to settle the transaction.

In other embodiments, the steps taken by the users of the MCD **2105** and **2107** to initiate and settle the final transaction may be different. For example, in some embodiments the process may be simplified where the user of the MCD **2107** sends the details of the proposed transaction along with its request to open a transaction session, allowing the user of the MCD **2105** to immediately accept the transaction.

Eventually, once the financial transaction is initiated and finalized (e.g., its details are agreed upon), the MCD **2105** may use the financial assets from its asset storage **1506** to settle (e.g., pay for) the financial transaction. More specifically, the MCD **2105** may settle the financial transaction with the MCD **2107** by transferring assets from the local asset storage **1506** of the MCD **2105** to the local asset storage **1508** of the MCD **2107**. In particular, the MCD **2105** communicates with the MCD **2107** via communication channel **1514** using the MCDs' respective short-range network interfaces **1405**. This exchange again involves directly communicating using peer-to-peer short-range wireless communication protocols, such as Bluetooth, Wi-Fi, near-field communication (NFC), Ultra-wideband (UWB), or IEEE 1902.15.4.

At a high-level, this step is to "settle" (e.g., "pay for") the financial transaction in the same way that an exchange of traditional currency settles a financial transaction. Indeed, a result of this step is that the financial assets are transferred from the MCD **2105** to the MCD **2107**. A consideration of this process is how the financial assets are transferred to the MCD **2107**. In some embodiments, this transfer includes information in addition to the financial assets. For example, as discussed in further detail below, in some embodiments encrypted information about the user account associated with the financial assets is also included in the transfer. This information is useful in preventing or mitigating the possibility of fraud, particularly with respect to double-spend attacks.

FIG. **17** is a flowchart illustrating a process of transferring funds from a financial service provider to a mobile wallet for an MCD, such as previously described in the first step of FIG. **16**. To start, the user of MCD **2105** interacts with mobile wallet logic **1408** (running on the MCD **2105**) to add funds to locally-stored mobile wallet **1506**.

In some embodiments, the mobile wallet logic **1408** may be part of a mobile wallet application (a mobile wallet app). As part of its functioning, the mobile wallet logic **1408** may be linked to the user's user account **1510** at financial service provider **1517**. The mobile wallet logic **1408** may also be linked to the local asset storage **1506**. The mobile wallet logic **1408** may track the value of the financial assets stored within the user account **1510** (i.e., the balance of user account **1510**), which it may display to the user. Similarly, the mobile wallet logic **1408** may track the value of the financial assets stored locally within local asset storage **1506** and display this value to the user. Showing these two values may allow a user to better judge when he or she should add funds to the local asset storage **1506**. The mobile wallet logic **1408** may be configured to update the recorded values for the balance of user account **1510** and local asset storage **1506** whenever their balances change, such as when funds are transferred between the user account **1510** and local asset storage **1506**.

After the user of MCD **2105** interacts with mobile wallet logic **1408** (running on the MCD **2105**) to add funds to locally-stored mobile wallet **1506**, the mobile wallet logic **1408**, in response, sends to financial service provider system **2103**, via network interface **1404**, a request for a transfer of financial assets from the user account **1510** to the linked mobile wallet **1506**.

After the mobile wallet logic **1408** sends to the financial service provider system **2103**, via network interface **1404**, a request for a transfer of financial assets from the user account **1510** to the linked mobile wallet **1506**, the financial service provider system **2103**, upon receiving and authenticating the request, sends a reply containing the requested amount of financial assets; concurrently, the financial service provider system **2103** debits the transferred assets from the user account **1510**.

After the financial service provider system **2103** sends a reply containing the requested amount of financial assets, the MCD **2105** receives the reply and stores the transferred assets in mobile wallet **1506**. After the MCD **2105** receives the reply and stores the transferred assets in mobile wallet **1506**, the process is complete.

FIG. **18** is a flowchart illustrating a process of locally initiating a financial transaction, such as previously described in the second step of FIG. **16**. To start, the user of the MCD **2105** interacts with the mobile wallet logic **1408** (running on the MCD **2105**) to discover other nearby MCDs.

After the user of the MCD **2105** interacts with the mobile wallet logic **1408** (running on the MCD **2105**) to discover other nearby MCDs, the mobile wallet logic **1408** indicates, when the MCDs **2105** and **2107** are in sufficient proximity to one another for communication. As an example, when the MCDs **2105** and **2107** are within range of each other, the MCD **2107** may be configured to send an identifier unique to the MCD **2107** or the user of the MCD **2107** (e.g., a phone number or name associated with the device **2107** or the user of the device **2107**), and the mobile wallet logic **1408** of the MCD **2105** may display such information to the user of the MCD **2105**.

In some embodiments, the mobile wallet logic **1408** may sort or filter which nearby MCDs are shown by some criteria. For example, in some embodiments, the list of nearby MCDs may be ordered by proximity, with the proximity being estimated based on the strength of the signal received from each nearby MCDs. As another example, in some embodiments the list of nearby MCDs may be filtered to show only MCDs that are running some form of mobile wallet logic that is compatible with the mobile wallet logic **1408**. Similarly, in some embodiments the list of nearby MCDs may be filtered to show only MCDs that have their form of mobile wallet logic actively open or that have actively provided input to their mobile wallet logic to expect a transaction.

Next, the user of the MCD **2105** selects the MCD **2107** and initiates a financial transaction. For example, upon viewing the displayed information identifying the MCD **2107**, the user of the MCD **2105** may provide an input for selecting the MCD **2107**, thereby confirming that the financial transaction is to occur with this MCD **2107**. After the user of the MCD **2105** selects the MCD **2107** and initiates a financial transaction, the process of FIG. **18** is complete.

Note that NFC may be used to help ensure that the digital funds are transferred to the correct MCD **2107**. In this regard, in NFC, the MCDs **2105** and **2107** are permitted to communicate only at a very short range, such as just a few inches. As such, it is unlikely that the MCD **2105** will be within range of a device other than the intended MCD **2107** during the transaction. Note that similar effects may be achieved with other protocols, such as RFID, depending on the communication range. For example, with Bluetooth, the communication range can extend much further, such as tens of feet, such that there is a realistic probability that multiple communication devices may in range of the MCD **2105** at the time of the transaction. In such an embodiment, other security measures may be employed to ensure that the assets are transferred to the appropriate MCD **2107**.

In some embodiments, such as when NFC is used, the user of the MCD **2105** may provide inputs indicating or confirming the amount (e.g., dollar value) of the transfer and when the user is ready transfer the specified amount. In some embodiments this input may include the expected amount of the transaction from the perspective of the user of the MCD **2105**, which the MCD **2105** may automatically compare to the value already present in the proposed transaction. If the values do not match, the MCD **2105** may display an alert to this user indicating that there is a mismatch.

One way the user of the MCD **2105** may provide this input is through touching a prompt shown on the touchscreen of the MCD **2105**. Another way the user of the MCD **2105** may provide this input is by "tapping" the MCD **2105** against the MCD **2107**. "Tapping" the MCD **2105** against the MCD **2107** may involve bringing the MCD **2105** (usually its back surface) into physical contact with the MCD **2107** (usually its back surface) and then brining the devices apart. Alternatively, "tapping" may involve bring the MCD **2105** into close physical proximity without touching—particularly so that they are communication range of one another—and then pulling the devices farther apart. In either case, during the tap, the MCD **2107** may communicate its identifier to the MCD **2105**, which then transfers the specified amount of financial assets if the received identifier matches the one previously selected or otherwise approved by the user of the MCD **2105** for the transaction.

In such an embodiment, it is possible for the transfer to occur in a multi-tap process. Specifically, in a first tap between the MCDs **2105** and **2107**, the MCD **2107** may transmit information about the transaction to the MCD **2105**, such as the amount of the transaction and the identifier of the MCD **2107**. During this first tap, the MCDs **2105** and **2107** may also exchange information to confirm that both devices have compatible resources for transferring the financial assets and completing the transaction. Upon receiving information about the transaction from the MCD **2107**, the mobile wallet logic **1408** of the communication device **2105** may store the identifier and display a prompt to the user of the MCD **2105** requesting the user to confirm the transaction. Such prompt may include the amount of the transfer (as well as other information about the transaction, such as information received from the MCD **2107** during the first tap) and, if desired, the identifier received from the MCD **2107**. Upon viewing such information, the user may provide an input confirming whether the transfer is authorized. If the amount of the transfer is not received from the MCD **2107**, the user may also provide an input indicating the amount of the transfer.

Once the user of the MCD **2105** has confirmed the transaction, a second tap may be performed to permit the financial assets to be transferred from the MCD **2105** to the MCD **2107**. As noted above, the mobile wallet logic **1408** of the MCD **2105** may transfer the financial assets based on an identifier received from the MCD **2107** during this second tap. In the current example, the mobile wallet logic **1408** may compare the identifier received from the MCD **2107** during the second tap to the identifier received during the first tap. If the compared identifiers match, thereby indicating that the MCD **2105** is currently communicating with the same MCD **2107** that provided the transaction information approved by the user of the MCD **2105**, then the mobile wallet logic **1408** of the MCD **2105** may transfer the specified financial assets to the MCD **2107**.

It should be emphasized that the two-tap transfer process described above is exemplary, and it is possible to transfer the financial assets using a different number of taps or not using taps at all. For example, in some embodiments the discovery of the MCD **2107** and the transfer of transaction information between the MCD **2105** and the MCD **2107** may occur based on user input to the devices without any taps being involved. Similarly, the confirmation and transfer of financial assets between the MCD **2105** and the MCD **2107** may occur based on user input confirming and finalizing the transaction, also without any taps being involved. This communication may happen over a variety of short-range communications protocols, such as Bluetooth or RFID.

As another example of the process described in FIG. **18** in the context of a buyer who is purchasing goods or services from a seller. After negotiating the transaction between themselves, the buyer and seller may initiate a financial transaction on their respective MCDs **2105** and **2107**. To do so, the seller may have initialized his or her mobile wallet application to prime the MCD **2107** to initiate a financial transaction with another MCD (e.g., MCD **2105**). The buyer and seller may then tap their MCDs **2105** and **2107** together, which prompts the MCDs to exchange information via near-field communication (NFC) for establishing a secure (financial) transaction session.

In some embodiments, the exchange of information allows the MCDs **2105** and **2107** to set up a communication channel using a different, higher-bandwidth (and slightly longer-range) short-range communications protocol, such as Bluetooth or Wi-fi Direct for the remainder of the transaction, though establishing such a secondary channel is unnecessary. In any event, before or after establishing the communication channel, the seller may provide input to his or her MCD **2107** specifying information about the financial transaction. Such information may include the amount owed/to be payed (i.e., the amount of financial assets to be transferred), but also possibly including other information, such as the goods or services being bought. Once the information is entered, the seller may provide input directing the mobile wallet logic **1408** running on the MCD **2107** to send the details of the transaction to the MCD **2105** and prompt the user of the MCD **2105** to accept and settle (i.e., pay for) the transaction.

Once the details of the transaction are sent from the MCD **2107** to the MCD **2105**, the MCD **2105** (specifically, the mobile wallet logic **1408** running on the MCD **2105**) may prompt the user to accept or reject the financial transaction. The user may then provide input doing so. As a security measure—in the sense of ensuring that the user meant to accept—the process of settling the "accepted" transaction and transferring the locally stored financial assets to the MCD **2107** may require a final step of the two MCDs again being tapped against one another, as described above. However, this final tapping of the MCDs is unnecessary in other embodiments.

Note that, this sequence of events could differ in various embodiments. For example, in some embodiments the seller could preemptively enter the details of the transaction before initiating the transaction session with the MCD **2105** (i.e., with the buyer). In this case, the buyer may immediately be shown the details of the proposed transactions and prompted to accept or decline them.

FIG. **19** is a flowchart illustrating a process of locally settling a financial transaction, such as previously described in the third step of FIG. **16**. To start, the user of the MCD **2105** interacts with the mobile wallet logic **1408** (running on the MCD **2105**) to settle the financial transaction.

After the user of the MCD **2105** interacts with mobile wallet logic **1408** (running on the MCD **2105**) to settle the financial transaction, the mobile wallet logic **1408**, in response, generates a transaction settlement data token **2002** containing a header **2003**, transaction data **2004**, encrypted user account information **2005**, and a financial asset payload **2006** containing the financial assets **2007** being used to settle the financial transaction. Next, the mobile wallet logic **1408** sends the data token to the MCD **2107** via short-range communications interface **1405**. The MCD **2107** subsequently receives and verifies the transaction settlement data token **2002** sent by MCD **2105**.

The MCD **2107** also stores the financial assets **2007** from the financial asset payload **2006** in the transaction settlement data token **2002** in its local asset storage **1508** and communicates with the MCD **2105** confirming it has received and accepted the transaction settlement data token **2002** as settlement of the financial transaction. At this point, the process shown by FIG. **19** is complete.

FIG. **20** is a block diagram of a data token used to locally settle a financial transaction, such as the data token described in FIG. **19**. As shown by the figure, a transaction settlement data token (TSDT) **2002** may comprise a header **2003**, transaction data **2004**, user account information **2005**, and a financial asset payload **2006**. The header **2003** may contain technical information usable by a MCD **1402** (e.g., MCD **2107**) to identify and process the transaction TSDT **2002**. In contrast, the transaction data **2004** may contain data detailing specifics about the financial transaction being settled, such as the dollar amount owed, the time of the transaction, etc. The financial asset payload **2006** may contain one or more financial assets **2007** which, as discussed above, are being transferred from the MCD **2105** to the MCD **2107** to settle the financial transaction.

Relatedly, the user account information **2005** contains information identifying the user account from which the financial assets **2007** were transferred. As an example, for the transaction discussed in FIG. **16**, the user account information **2005** contains information about user account **1510** at the financial service provider **1517** (that is accessible and controlled by financial service provider system **2103**), since it is this account from which the financial assets were transferred. Thus, the user account information **2005** may contain identifying information about the user account **1510**, such as the account number. The user account information **2005** may also contain information related to the user account **1510**, such as the identity of the financial service provider **1517** (or, similarly, the identity of the financial service provider system **2103**) or the identity (e.g., name) of the owner of the user account **1510**. Note that, in some embodiments the transaction settlement data token **2002** may not include the header **2003** or the transaction data **2004**.

In some embodiments, the user account information **2005** may be encrypted before being sent to the MCD **2107** such that only other financial service providers (or similar financial institutions) can decrypt and retrieve the associated data. This is useful to preserve the anonymity of the user of the MCD **2105** relative to the user of the MCD **2107** while still allowing the owner of the MCD **2107** (and of user account **1512**) to have recourse—via their financial service provider **1518** (i.e., the entity associated with the financial service provider system **2109**)—in the case of a fraudulent double-spend attack.

One aspect of the transaction settlement data token is how the financial assets **2007** may be structured so as to enable an offline transfer of value. In some embodiments, the financial asset **2007** may be structured or represented as un-submitted but fully authenticated and valid transaction transferring an appropriate amount of financial assets.

For example, if the financial assets being transferred are a cryptocurrency, the financial assets **2007** may comprise an un-submitted but fully authenticated and valid cryptocurrency transaction transferring an appropriate amount of cryptocurrency. As a more concrete example, if the financial assets being transferred are Bitcoins, the financial assets **2007** may comprise an un-submitted but fully authenticated and valid cryptocurrency transaction transferring an appropriate amount of cryptocurrency from a Bitcoin address to some other Bitcoin address.

The nature of these un-submitted but fully authenticated cryptocurrency transactions, along with the Bitcoin address they are being sent from and the Bitcoin address they are being sent to, may vary depending on different design decisions. These different designs may affect the ease of use of the system and its relative robustness against fraud, and may be made on the basis of balancing these factors.

For example, in some embodiments, each of the financial assets stored on the local asset storage **1506** of the MCD **2105** may be a private key associated with a corresponding Bitcoin address having a certain (preferably but not necessarily standardized) amount of Bitcoins. In embodiments using this approach, a financial asset **2007** may be an un-submitted but fully authenticated transaction transferring the Bitcoins from one of these Bitcoin addresses (that has not been used previously and is not being simultaneously used by another financial asset **2007**). Multiple of these financial assets **2007** may be used to meet or exceed the necessary amount of value to be transferred. In a case where the transaction contains more value than is necessary for the present transaction, the remaining value of Bitcoin may be transferred in a second output to a Bitcoin address controlled by the user of the MCD **2105**.

Also for embodiments using this approach, one Bitcoin address that the un-submitted but fully authenticated transaction specifies in its output may vary. In some embodiments, the MCD **2105** may itself create a new public-private key pair (with the public key being the new Bitcoin address) and use the newly created Bitcoin address as the output destination of the un-submitted but fully authenticated transactions. In this case, the MCD **2105** may include as part of the financial asset payload **2006** the private key corresponding to the newly created Bitcoin address. The user of the mobile device **2107** may then utilize this private key to generate a second cryptocurrency transaction to transfer the cryptocurrency assets from the newly created cryptocurrency address to an address of his or her choosing. The MCD **2107** may then later submit both these transactions to the broader Bitcoin network.

Alternatively, in some embodiments the MCD **2105** may request the MCD **2107** to specify the Bitcoin address (i.e., a public key to require in the locking script) that the un-submitted but fully authentication transactions should specify in their output. The MCD **2107** could provide this information, either by referencing the public key of an existing Bitcoin address or generating a new public-private key pair.

Also note that, in some embodiments, the TSDT **2002** may include information about a backing financial institution guaranteeing the funds being transferred. This may be accompanied by a signature that could be verified by the MCD **2107**. This guarantee may be in the form of a promise to pay the recipient (i.e., the user of the MCD **2107**) even in the case of a fraudulent double-spend attack or to guarantee that a certain amount of funds of the user of the MCD **2105** are being held for a certain amount of time for the same purpose. The benefit of this inclusion is that the presence of a large (and presumably trust-worthy) financial institution guaranteeing payment may make the user of a MCD **2107** more willing to accept the financial assets **2007** as payment. This guarantee may, in some embodiments, include a timestamp and a caveat that it is only valid for a certain duration starting from that time, which may essentially require or encourage the user of the MCD **2107** to connect to a network within that duration.

In some embodiments, the mobile wallet logic **1408** running on the MCD **2105** could be configured to display a notification to a user that a peer-to-peer transaction has occurred that has not yet been finalized with the relevant financial institutions. In some embodiments, a peer-to-peer transaction may be finalized when the MCD **2107** transfers the financial assets received from the MCD **2105** to the user account **1512** associated with the MCD **2107**. When the financial service provider **1518** (i.e., when the financial service provider system **2109**) receives and verifies the transferred financial assets, the financial service provider system **2109** may communicate with the financial service provider system **2103** over communication channel **1516** to inform the financial service provider system **2103** that it has accepted the financial assets that originated from user account **1510**. Subsequently, the financial service provider system **2103** may communicate with the MCD **2105** (specifically, with the mobile wallet logic **1408** running on the MCD **2105**) that the relevant peer-to-peer financial transaction has been finalized. The MCD **2105** may then display an updated notification to the user indicating that the peer-to-per transaction has been formally accepted and finalized.

In some embodiments, the financial assets being transferred from the user account **1510** at the financial service provider **1517** may comprise one or more cryptocurrencies. In addition, one or more of the cryptocurrency financial assets may be associated with a cryptocurrency address. The cryptocurrency address may be configured such that it has an associated pool of private keys of which a quorum is required to approve and effectuate a transfer of the cryptocurrency assets associated with the cryptocurrency address, as described above with reference to cryptocurrency management system **102**. In this regard, the same techniques described above for authenticating a transfer of digital currency in a cryptocurrency management system **102** depicted by FIG. **1** may be used to authorize a transfer of cryptocurrency from the financial service provider system **2103** (specifically from the user account **1510** at the financial service provider system) to the MCD **2105**. As an example, the MCD **2105** may function in the same manner described above for the MCD **105** of FIG. **1** for the authorization. However, in other embodiments, use of such transfer authorization techniques is unnecessary. In another example, similar techniques may be used to authorize a transfer of cryptocurrency from the MCD **2105** to the MCD **2107**.

It should be noted that, the relational terms herein such as "first" and "second" are used only to differentiate an entity or operation from another entity or operation, and do not require or imply any actual relationship or sequence between these entities or operations. Moreover, the words "comprising," "having," "containing," and "including," and other similar forms are intended to be equivalent in meaning and be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items.

In the foregoing specification, embodiments have been described with reference to numerous specific details that can vary from implementation to implementation. Certain adaptations and modifications of the described embodiments can be made. Other embodiments can be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the disclosure being indicated by the following claims. It is also intended that the sequence of steps shown in figures are only for illustrative purposes and are not intended to be limited to any particular sequence of steps. As such, those skilled in the art can appreciate that these steps can be performed in a different order while implementing the same method.

Now, therefore, the following is claimed:

1. A method for locally authenticating an anonymous peer-to-peer transaction, the method comprising:

displaying, on a user interface presented by a display of a first mobile communication device (MCD), an account value of financial assets stored within a first user account at a first financial service provider system, wherein at least a subset of the financial assets stored within the first user account are stored in a remote storage associated with the first financial service provider system, wherein the financial assets include a cryptocurrency;

initiating, in response to user input received via the user interface, a communication request to transfer a specified value of financial assets through a communication network from the remote storage at the first user account at the first financial service provider system into local asset storage in a non-volatile memory of the first MCD that is configured to conduct at least one local transaction via a near-field wireless channel, wherein the user input is associated with the at least one local transaction;

upon receiving an acknowledgement communication from the first financial service provider system, increasing

a balance of locally stored financial assets based on the specified value of the financial assets received in the acknowledgement communication by storing the financial assets in the local asset storage in the non-volatile memory of the first MCD, wherein the acknowledgement communication further causes the first user account to be debited the specified value;

initiating a transaction settlement protocol to transfer a first value from the locally stored financial assets on the first MCD to a second MCD over the near-field wireless channel based on a proximity between the first MCD and the second MCD and a secure transaction session of the transaction settlement protocol;

upon receiving an authenticated transaction settlement communication from the second MCD, generating a transaction settlement data token comprising transaction data containing information specific to a local transaction request associated with the at least one local transaction, the first value, and encrypted personal information relating to the first user account at the first financial service provider system, wherein the encrypted personal information is associated with an identity verification;

transmitting the transaction settlement data token to the second MCD over the near-field wireless channel;

receiving, at the first MCD over the near-field wireless channel, confirmation of transmission of the transaction settlement data token from the second MCD, wherein the second MCD verifies the transaction settlement data token prior to sending the confirmation of transmission; and

debiting the locally stored financial assets stored on the first MCD according to the first value upon receiving the confirmation of transmission.

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

upon receiving the confirmation of transmission of the transaction settlement data token to the second MCD, updating the user interface to present a visual identifier indicating that an unsettled peer-to-peer transaction is pending final settlement with a second financial service provider system associated with the second MCD; and

upon receiving a transaction settled notification from the first financial service provider system, updating the visual identifier presented by the user interface to indicate that the unsettled peer-to-peer transaction has fully settled to a second user account at the second financial service provider system associated with the second MCD.

3. The method of claim **1**, wherein the first value being transferred comprises at least one un-submitted but fully authenticated transaction with an output specifying a second user account at a second financial service provider system linked to the second MCD.

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

displaying, on the user interface presented by the display of the first MCD, a list indicating a plurality of MCDs within range of the first MCD, wherein the plurality of MCDs includes the second MCD; and

in response to receiving, via the user interface, user input selecting the second MCD from the list, sending, from the first MCD to the second MCD over the near-field wireless channel, a request for a transaction session.

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

responsive to receiving confirmation from the second MCD of receiving and accepting the request for the transaction session:

updating the user interface to indicate the request for the transaction session was accepted; and

further updating the user interface to receive input from a user of the first MCD (1) specifying details about a proposed financial transaction and (2) indicating the proposed financial transaction is finalized and ready for settlement.

6. The method of claim **1**, wherein:

the financial assets stored within the first user account comprise one or more cryptocurrency tokens associated with a cryptocurrency address of a cryptocurrency network;

a transfer of the one or more cryptocurrency tokens from the first user account requires the transfer to be authenticated by obtaining at least a minimum-threshold number of authenticating signatures sufficient to form a quorum of authenticating signatures, wherein:

the quorum of authenticating signatures includes a first authenticating signature and either a second authenticating signature or a third authenticating signature;

the first authenticating signature is generated using a first authenticating key share from a pool of authenticating key shares associated with the cryptocurrency address;

the second authenticating signature is obtained from a cryptocurrency management device (CMD) and is generated using a second authenticating key share from the pool of authenticating key shares, wherein the second authenticating key share is stored on the CMD; and

the third authenticating signature is obtained from a cryptocurrency management server (CMS) and is generated using a third authenticating key share from the pool of authenticating key shares, wherein the third authenticating key share is stored on the CMS; and

the method further comprises:

storing, in the non-volatile memory of the first MCD, the first authenticating key share;

prior to sending the communication request to import the specified value of financial assets:

initiating a transaction involving one or more cryptocurrency tokens associated with the cryptocurrency address; and

obtaining at least the minimum-threshold number of authenticating signatures sufficient to form the quorum of authenticating signatures by communicating with either the CMD or the CMS;

generating an authenticated transaction using the quorum of authenticating signatures; and

attaching to the communication request to import the specified value of financial assets the authenticated transaction.

7. The method of claim **6**, wherein the obtaining comprises:

transmitting a signature request comprising authenticating information and transaction information from the first MCD to the CMS, wherein the authenticating information is sufficient to authenticate the first MCD to the CMS and the transaction information comprises information detailing the initiated transaction; and

receiving, at the first MCD from the CMS, a signature reply comprising the third authenticating signature, wherein the signature reply was generated by the CMS using the transaction information and the CMS required the initiated transaction to conform to a transaction policy associated with the cryptocurrency address before the CMS generated the third authenticating signature.

8. The method of claim **6**, wherein the obtaining comprises:

transmitting a signature request comprising authenticating information and transaction information from the first MCD to the CMD, wherein the authenticating information is sufficient to authenticate the first MCD to the CMD and the transaction information comprises information detailing the initiated transaction; and

receiving, at the first MCD from the CMD, a signature reply comprising the second authenticating signature, wherein the signature reply was generated by the CMD using the transaction information and the CMD required a user to provide biometric information directly to the CMD before the CMD generated the second authenticating signature.

9. A method for authenticating a local peer-to-peer transaction using a first mobile communication device (MCD), the method comprising:

receiving, with the first MCD through a communication network, financial assets from a first user account at a first financial service provider system of a first financial service provider, wherein at least a subset of the financial assets are transferred from a remote storage of the first user account associated with the first financial service provider system, wherein the financial assets include a cryptocurrency;

storing the financial assets in local asset storage located in a non-volatile memory of the first MCD that is configured to conduct at least one local transaction, wherein the local asset storage is linked to the first user account;

initiating a local financial transaction associated with the at least one local transaction with a second MCD using a near-field wireless channel between the first MCD and the second MCD, wherein the local financial transaction is for a specified monetary value; and

settling the local financial transaction using the financial assets stored in the local asset storage by:

generating, at the first MCD, a transaction settlement data token comprising transaction data, encrypted personal information, and a portion of financial assets associated with the specified monetary value, wherein the encrypted personal information is associated with an identity verification;

transferring at least the portion of the financial assets from the local asset storage to the second MCD by transmitting the transaction settlement data token to the second MCD over the near-field wireless channel based on a proximity between the first MCD and the second MCD and a secure transaction session of a transaction settlement protocol; and

upon receiving confirmation of transmission of the transaction settlement data token from the second MCD, removing the portion of the financial assets included in the transaction settlement data token from the local asset storage.

10. The method of claim **9**, wherein the portion of the financial assets being transferred comprises at least one un-submitted but fully authenticated transaction with an output specifying a second user account at a second financial service provider.

11. The method of claim **9**, wherein the method further comprises:

receiving, at the first MCD in a first near-field communication (NFC) tap between the first MCD and the second MCD, a first identifier associated with the second MCD;

receiving, at the first MCD in a second NFC tap between the first MCD and the second MCD, a second identifier associated with the second MCD; and

comparing, at the first MCD, the first identifier and the second identifier, wherein the transferring at least the portion of the financial assets is performed in the second NFC tap based on the comparing.

12. The method of claim **9**, further comprising:

displaying, on a user interface of the first MCD, a list indicating a plurality of MCDs within range of the first MCD, wherein the plurality of MCDs includes the second MCD; and

responsive to receiving input selecting the second MCD from the list, sending, from the first MCD to the second MCD over the near-field wireless channel, a request for a transaction session.

13. The method of claim **9**, further comprising:

receiving, at the first MCD, a message from the second MCD specifying details about the local financial transaction;

displaying, at the first MCD, the details about the local financial transaction; and

displaying, at the first MCD, a prompt requesting a user to accept the local financial transaction.

14. A first mobile communication device (MCD) for authenticating a local peer-to-peer transaction, comprising:

network interface circuitry configured to communicate with a first financial service provider system of a first financial service provider over a communication network;

near-field communications interface circuitry configured to communicate with a second MCD over a near-field wireless channel;

a non-volatile memory of the first MCD that includes local asset storage configured to store a balance of locally stored assets transferred from a first user account at the first financial service provider system, wherein the locally stored assets are transferred from a remote storage of the first user account associated with the first financial service provider system; and

at least one processor configured to:

receive financial assets from the remote storage of the first user account associated with the first financial service provider system through the communication network, wherein the financial assets include a cryptocurrency;

store the financial assets in the local asset storage in the non-volatile memory of the first MCD;

initiate a local financial transaction with the second MCD via communications using the near-field communications interface circuitry, wherein the local financial transaction is for a specified monetary value; and

settle the local financial transaction using the financial assets stored in the local asset storage by:

generating a transaction settlement data token comprising transaction data, encrypted personal information, and a portion of financial assets associated with the specified monetary value, wherein the encrypted personal information is associated with an identity verification;

transferring at least the portion of the financial assets from the local asset storage to the second MCD by transmitting the transaction settlement data token to the second MCD using the near-field communications interface circuitry based on a proximity between the first MCD and the second MCD and a secure transaction session of a transaction settlement protocol; and

upon receiving confirmation of transmission of the transaction settlement data token to the second MCD, removing the portion of financial assets included in the transaction settlement data token from the local asset storage.

15. The first mobile communication device of claim **14**, wherein the portion of the financial assets being transferred comprises at least one un-submitted but fully authenticated transaction with an output specifying a second user account at a second financial service provider.

16. The first mobile communication device of claim **14**, wherein the at least one processor is further configured to:

receive, using the near-field communications interface circuitry in a first NFC tap between the first MCD and the second MCD, a first identifier associated with the second MCD;

receive, using the near-field communications interface circuitry in a second NFC tap between the first MCD and the second MCD, a second identifier associated with the second MCD;

compare the first identifier and the second identifier; and

transfer at least the portion of the financial assets to the second MCD in the second NFC tap based on a comparison of the first identifier and the second identifier.

17. The first mobile communication device of claim **14**, wherein the at least one processor is further configured to:

display, on a user interface of the first MCD, a list indicating a plurality of MCDs within range of the first MCD, wherein the plurality of MCDs includes the second MCD; and

in response to receiving input selecting the second MCD from the list, send a communication request from the first MCD to the second MCD requesting a transaction session using the near-field wireless channel.

18. The first MCD of claim **14**, wherein the at least one processor is further configured to:

receive a message from the second MCD specifying details about the local financial transaction;

display, at the first MCD, the details about the local financial transaction; and

display, at the first MCD, a prompt requesting a user to accept the local financial transaction.

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