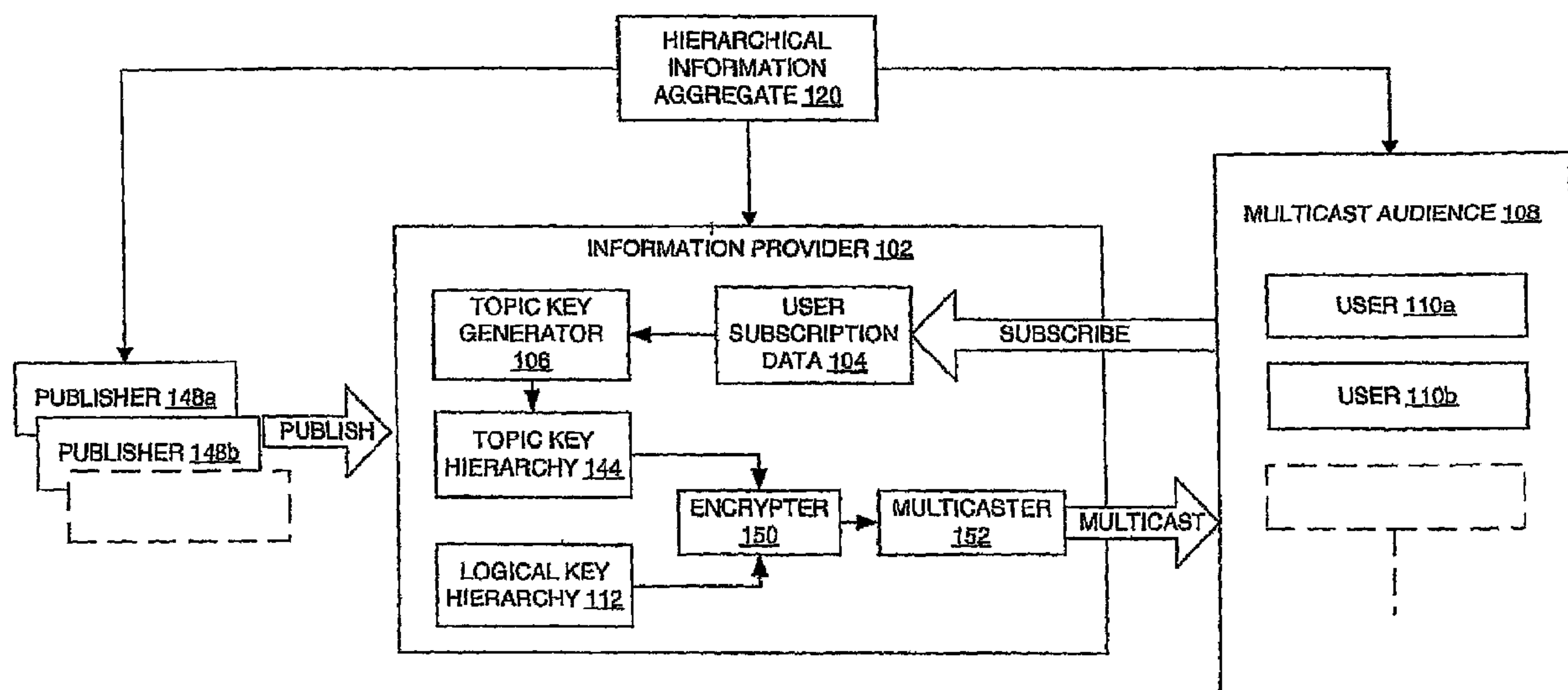




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(54) **Titre : CONTROLE D'ACCES DANS UN SYSTEME MULTI-DIFFUSION**
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(57) **Abrégé/Abstract:**

A multicast host for communicating information published about any one of a set of topics to one or more authorised subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the host comprising: means for receiving information relating to a topic; means for determining a partition element for the topic; means for retrieving a partition element encryption key associated with the partition element; means for encrypting the information with the retrieved partition element encryption key; and means for communicating the information to the one or more authorised subscribers.



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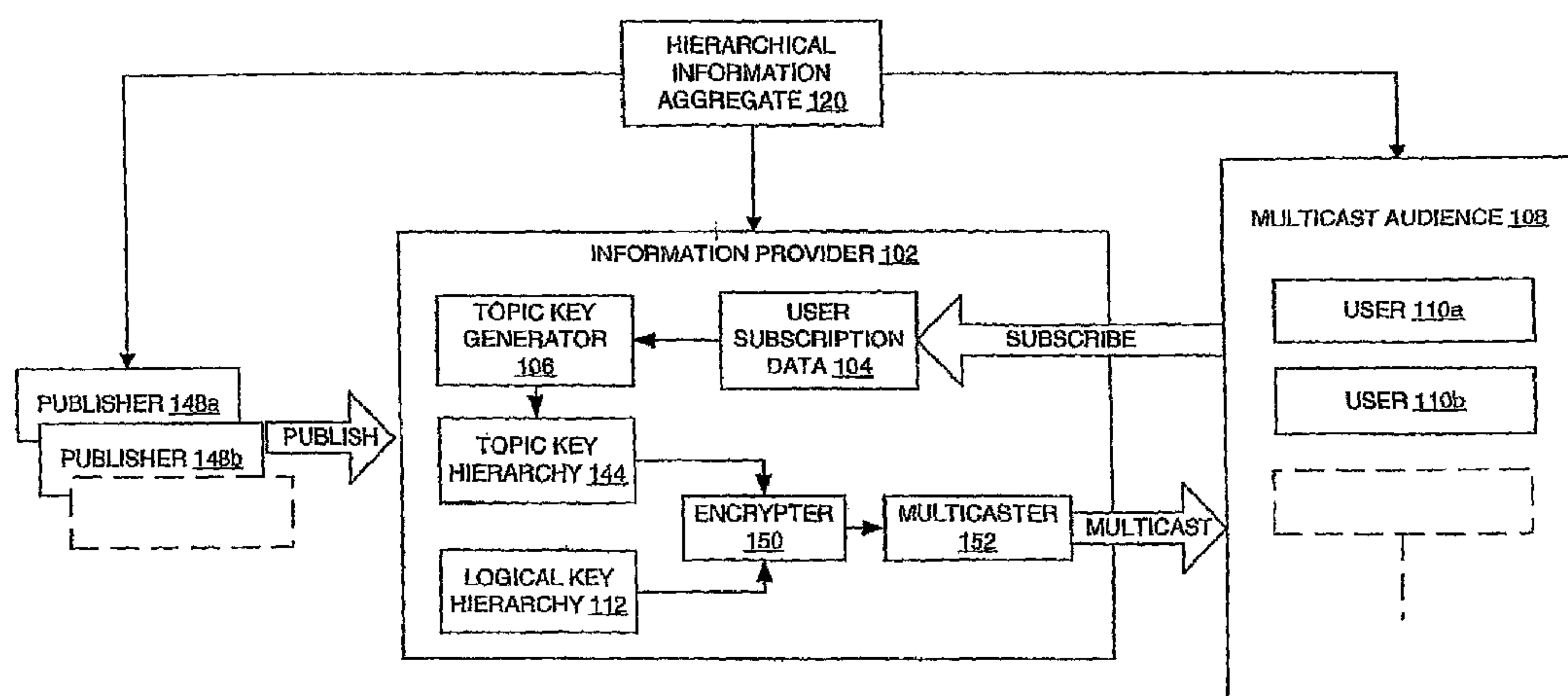
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(54) Title: ACCESS CONTROL OVER MULTICAST



(57) Abstract: A multicast host for communicating information published about any one of a set of topics to one or more authorised subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the host comprising: means for receiving information relating to a topic; means for determining a partition element for the topic; means for retrieving a partition element encryption key associated with the partition element; means for encrypting the information with the retrieved partition element encryption key; and means for communicating the information to the one or more authorised subscribers.

WO 2006/000566 A1

WO 2006/000566 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Description

ACCESS CONTROL OVER MULTICAST

Technical Field

- [001] This invention relates to providing access control for published information. In particular it relates to access control in a multicast publish/subscribe system.

Background Art

- [002] In publish/subscribe systems information can be organised as an hierarchy of topics known as an hierarchical information aggregate. A user is able to subscribe to receive information published to one or more of the topics. When information is published to a topic in the information aggregate an information provider securely communicates the information as a message to a set of users in such a way that only a subset of the users who are subscribed to the topic are able to access the message. To ensure the message is communicated securely and can only be accessed by subscribed users it is necessary for the information provider to encrypt the message using a key based encryption method such as public/private key encryption.
- [003] One way to ensure published information is only accessible to subscribed users is to use an unicast publish/subscribe system. In an unicast system an information provider determines a set of users subscribed to a topic to which information is published. For each subscribed user a communications channel between the information provider and the subscribed user is used to communicate the published information as a message to the subscribed user. The communications channel is secured using a key for the subscribed user and a separate communications channel exists for each subscribed user. In this way published information is securely delivered to each subscribed user using separate communications channels so ensuring only subscribed users receive and can access the published information. Unicast publish/subscribe systems have the disadvantage that a communications channel must exist for each subscribed user and that published information must be communicated separately for each user.
- [004] An alternative to an unicast publish/subscribe system is a multicast publish/subscribe system which does not include a separate communications channel for each user. In a multicast system published information is communicated as a message to subscribed users over a communications channel which is common to multiple users, potentially including users which are not subscribed. To ensure the message is accessible only to subscribed users it is encrypted once for each subscribed user using a key specific to the user. Once encrypted for a subscribed user, the message is communicated over the common communications channel. Only the user for which the message was encrypted is able to access the published information using the user's

specific key. Such a multicast publish/subscribe system has the disadvantage that a message containing published information must be encrypted and securely communicated once for each subscribed user. This is resource intensive especially where there are many subscribed users.

- [005] The paper "Secure Group Communications Using Key Graphs" (Wong et al, IEEE/ACM Transactions on Networking, Vol. 8, No. 1, Feb 2000 pp. 16-30) discloses a technique to partially alleviate these problems by using a hierarchy of keys, known as a logical key hierarchy. Wong et al. describe representing users in a multicast audience as leaf nodes in a logical tree. Each node contains a key and each user has knowledge of every key in the path from its leaf to the root of the tree. When information is published an information provider communicates the information as a message over a multicast communications channel. Prior to communication, the message is encrypted using a random key, K_r . An information provider then determines a set of keys which can be used to encrypt the random key K_r , where the set of keys corresponds to a set of subscribed users. Thus, the message is encrypted only once using the random key K_r , whilst the random key is itself encrypted multiple times using the set of keys corresponding to the subscribed users. Where all users in a branch of the logical tree are subscribers of the published information the key for the node representing the branch in the tree can be used to encrypt the random key K_r . In this way it is not necessary to encrypt the random key K_r using an individual key for each subscribed user. The logical key hierarchy approach described by Wong et al. therefore alleviates the problems with secure publish/subscribe distribution over a multicast communications channel by removing the need to encrypt a published information message more than once, and by reducing the set of keys required to accommodate a set of subscribed users.

- [006] While the logical key hierarchy approach is effective for simple published information structures, it has the drawback that it requires the generation of a random key K_r for each published information message. In a high volume system with frequent publication of information the repeated generation of random keys can be resource intensive. This is particularly pertinent to hierarchical information aggregates where users can have very fine grained subscriptions to particular and detailed topics in the information aggregate and the number of published information messages can be high. For example, a user may have specific subscription interests which may be very unlike other users, such as a stock quote system where each user subscribes to topics in an hierarchical information aggregate corresponding to stock quote information for particular stocks in a portfolio.

- [007] It would therefore be advantageous to securely communicate published information over a multicast communications channel without the need to generate a random key

for each published information message for information published in an hierarchical information aggregate.

Disclosure of Invention

- [008] The present invention accordingly provides, in a first aspect, a multicast host for communicating information published about any one of a set of topics to one or more authorised subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the host comprising: means for receiving information relating to a topic; means for determining a partition element for the topic; means for retrieving a partition element encryption key associated with the partition element; means for encrypting the information with the retrieved partition element encryption key; and means for communicating the information to the one or more authorised subscribers.
- [009] Thus the present invention provides the advantage that information published to a topic is encrypted using the topic key without the need for the generation of a random key for the multicast message. The topic key for a topic is distributed so that only users subscribed to the topic can access the topic key.
- [010] Preferably each disjoint proper subset of the set of topics is defined in accordance with an access control list.
- [011] Preferably the access control list includes a definition of a plurality of roles.
- [012] Preferably each of the plurality of roles is a subset of the set of topics.
- [013] Preferably each disjoint proper subset of the set of topics is defined to be one of a set difference and an intersect of the plurality of roles.
- [014] Preferably the multicast host further comprises means for securely communicating the partition element encryption key to the one or more subscribers.
- [015] Preferably the partition element encryption key is securely communicated by encrypting the partition element encryption key.
- [016] Preferably the partition element encryption key is encrypted using a logical key hierarchy in which a logical key corresponds to the one or more authorised subscribers.
- [017] Preferably the multicast host further comprises means for securely communicating a partition element decryption key to the one or more authorised subscribers, wherein the partition element decryption key corresponds to the partition element encryption key.
- [018] Preferably the partition element decryption key is securely communicated by encrypting the partition element decryption key.
- [019] Preferably the partition element decryption key is encrypted using a logical key hierarchy in which a logical key corresponds to the one or more authorised subscribers.

- [020] Preferably the multicast host further comprises means for receiving a new subscription to a topic in a partition element; and means for generating a new partition element encryption key for a partition element.
- [021] Preferably the multicast host further comprises means for generating a new partition element decryption key corresponding to the new partition element encryption key.
- [022] Preferably the multicast host further comprises means for receiving a cancelled subscription to a topic in a partition element; and means for generating a new partition element encryption key for a partition element.
- [023] Preferably the multicast host further comprises means for generating a new partition element decryption key corresponding to the new partition element encryption key.
- [024] The present invention accordingly provides, in a second aspect, multicast system comprising: a multicast host according to the first aspect; and one or more multicast subscribers for receiving information communicated by the multicast host.
- [025] The present invention accordingly provides, in a third aspect, a method for communicating information published about any one of a set of topics to one or more authorised subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the host comprising: receiving information relating to a topic; determining a partition element for the topic; retrieving a partition element encryption key associated with the partition element; encrypting the information with the retrieved partition element encryption key; and communicating the information to the one or more authorised subscribers.
- [026] The present invention accordingly provides, in a fourth aspect, a computer program product comprising computer program code stored on a computer readable storage medium which, when executed on a data processing system, instructs the data processing system to carry out the method described above in the third aspect.
- [027] The present invention accordingly provides, in a fifth aspect, a computer program product stored on a computer usable medium, the computer program product for communicating information published about any one of a set of topics to one or more authorised subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the computer program product comprising: computer readable program means for receiving information relating to a topic; computer readable program means for determining a partition element for the topic; computer readable program means for retrieving a partition element encryption key associated with the partition element; computer readable program means for encrypting

the information with the retrieved partition element encryption key; and computer readable program means for communicating the information to the one or more authorised subscribers.

Brief Description of the Drawings

- [028] Preferred embodiments of the present invention will now be described in detail by way of example only with reference to the following drawings:
- [029] Figure 1a is a schematic illustration of a multicast publish/subscribe system including a multicast information provider in accordance with a preferred embodiment of the present invention;
- [030] Figure 1b is an illustrative example of the hierarchical information aggregate of Figure 1a in accordance with a preferred embodiment of the present invention;
- [031] Figure 1c is an illustrative example of the topic key hierarchy of Figure 1a in accordance with a preferred embodiment of the present invention;
- [032] Figure 1d is an illustrative example of the logical key hierarchy 112 of Figure 1a as is known in the art;
- [033] Figure 1e is an illustrative example of a user which is associated with key A1 in the logical key hierarchy of Figure 1a by way of an indicator of Figure 1d;
- [034] Figure 1f is an illustrative example of a user which is associated with key A2 in the logical key hierarchy by way of an indicator of Figure 1d;
- [035] Figure 2 is a flow chart illustrating a method for publishing information in a multicast system in accordance with a preferred embodiment of the present invention; and
- [036] Figure 3 is a flow chart illustrating a method for regenerating topic keys in accordance with a preferred embodiment of the present invention;
- [037] Figure 4a is a schematic illustration of a multicast publish/subscribe system including a multicast information provider in accordance with a preferred embodiment of the present invention;
- [038] Figure 4b is an illustration of the access control list of Figure 4
- [039] in accordance with a preferred embodiment of the present invention;
- [040] Figure 5a is a flowchart of a method for defining the partition elements of Figure 4a in accordance with a preferred embodiment of the present invention;
- [041] Figure 5b is a flowchart illustrating a method for generating a list of disjoint subsets from a list of subsets in a preferred embodiment of the present invention;
- [042] Figure 5c is an illustrative example of the hierarchical information aggregate of Figure 4a, including a definition of subsets of the hierarchical information aggregate, in accordance with a preferred embodiment of the present invention;
- [043] Figure 5d illustrates disjoint proper subsets generated using the method of Figure 5b

for the hierarchical information aggregate of Figure 5c in accordance with a preferred embodiment of the present invention;

[044] Figure 6a is an illustrative example of the hierarchical information aggregate of Figure 4a in accordance with a preferred embodiment of the present invention;

[045] Figure 6b is a schematic diagram illustrating the access control list of Figure 4a and the hierarchical information aggregate of Figure 6a in accordance with a preferred embodiment of the present invention;

[046] Figure 6c is an illustrative example of the partition elements of Figure 4a in accordance with a preferred embodiment of the present invention;

[047] Figure 7a is an illustrative example of the logical key hierarchy of Figure 4a in accordance with a preferred embodiment of the present invention;

[048] Figure 7b is an illustrative example of a user which is associated with key F11 in the logical key hierarchy of Figure 4a by way of an indicator of Figure 7a;

[049] Figure 7c is an illustrative example of a user which is associated with key F121 in the logical key hierarchy of Figure 4a by way of an indicator of Figure 7a;

[050] Figure 7d is an illustrative example of a user which is associated with key F122 in the logical key hierarchy of Figure 4a by way of an indicator of Figure 7a;

[051] Figure 7e is an illustrative example of a user which is associated with key F2 in the logical key hierarchy of Figure 4a by way of an indicator of Figure 7a;

[052] Figure 8 is a flow chart illustrating a method for publishing information in a multicast system in accordance with a preferred embodiment of the present invention.

Mode for the Invention

[053] Figure 1a is a schematic illustration of a multicast publish/subscribe system including a multicast information provider 102. In the multicast publish/subscribe system publishers 148a and 148b are hardware or software implementations of devices or entities which publish information to topics in an hierarchical information aggregate 120. The hierarchical information aggregate 120 is a logical structure of topics arranged hierarchically to which information can be published and is considered in detail below with respect to Figure 1b. Information published by the publishers 148a and 148b is communicated to the information provider 102 over a communications channel between the publishers 148a and 148b. Examples of such communications channels include wired or wireless computer networks, although it will be appreciated by those skilled in the art that any communications channel between the publishers 148a and 148b and the information provider 102 can be used.

[054] The information provider 102 is a hardware or software implementation of a device or entity which receives published information from publishers 148a and 148b. The information provider includes a multicaster 152 which is a hardware or software device

or entity for communicating published information to a multicast audience 108 as multicast messages. A multicast message is a message that is sent to multiple devices or users on a network and is well known in the art. For example, multicaster 152 is a software application configured to send multicast messages to the multicast audience 108. The multicast audience 108 is a collection of users 110a and 110b. Users 110a and 110b are hardware or software implementations of devices or entities configured to receive multicast messages which correspond to published information from the information provider 102. For example, the information provider 102 can be a computer system communicatively connected to the multicast audience 108 and the published information can be data, such as binary data. An example of a connection between the information provider 102 and the multicast audience 108 is a computer network. The users 110a and 110b are able to subscribe to one or more topics in the hierarchical information aggregate 120 by communicating a subscription request to the information provider 102. The information provider 102 includes user subscription data 104 which stores information regarding subscriptions of users 110a and 110b to topics within the hierarchical information aggregate 120. For example, if user 110a is subscribed to a particular topic in the hierarchical information aggregate 120, this subscription is recorded in the user subscription data 104 including an identification of the user and an identification of the topic. The user subscription data 104 can be recorded in a database. Alternatively, the user subscription data 104 can be recorded in a memory of a computer system or as a file on a storage device of a computer system. It will be appreciated by those skilled in the art that other suitable means for storing the user subscription data 104 may be employed.

The information provider 102 further includes a topic key generator 106, a topic key hierarchy 144, a logical key hierarchy 112 and an encrypter 150. The topic key generator is a hardware or software device or entity for generating encryption keys, such as public keys and private keys required for public/private key encryption as is well known in the art. An example of a topic key generator 106 is the Pretty Good Privacy® (PGP®) product. The topic key generator 106 generates keys for each of the topics of the hierarchical information aggregate 120 and stores them in the topic key hierarchy 144. The topic key hierarchy 144 is considered in detail below with respect to Figure 1c. The logical key hierarchy 112 is a logical tree structure of keys as is known in the art and is considered in detail below with reference to Figure 1d. The encrypter 150 is a hardware or software device or entity for generating an encrypted version of a data item using one or more encryption keys. For example, the encrypter 150 can use a public encryption key to encrypt an item of data. An example of an encrypter 150 is the "Pretty Good Privacy" (PGP) product.

[056] In Figure 1a the multicast audience 108 is illustrated as having two users, although it will be apparent to those skilled in the art that any number of users could constitute the multicast audience 108. Similarly, whilst only two publishers 148a and 148b are illustrated, it will be apparent to those skilled in the art that any number of publishers could publish information in such a multicast publish/subscribe system.

[057] Figure 1b is an illustrative example of the hierarchical information aggregate 120 of Figure 1a. The hierarchical information aggregate 120 is stored in a storage or memory of a device (not illustrated) and is accessible to each of the publishers 148a, 148b, the information provider 102 and the users 110a and 110b in the multicast audience 108. Alternatively the hierarchical information aggregate 120 may be stored in a storage or memory of any one or more of the publishers 148a, 148b, the information provider 102 or the users 110a and 110b in the multicast audience 108, whilst being accessible to each of these devices or entities. The hierarchical information aggregate 120 comprises topic "NEWS" 122, topic "FINANCE" 124, topic "SPORT" 126, topic "BUSINESS" 128 and topic "PERSONAL" 130 arranged hierarchically such that topic "NEWS" 122 is a root topic in the hierarchy. The topics "FINANCE" 124 and "SPORT" 126 descend from topic "NEWS" 122, and the topics "BUSINESS" 128 and "PERSONAL" 130 descend from topic "FINANCE" 124. Each of the topics is a category to which information can be published by the publishers 148a and 148b. Users 110a and 110b are able to subscribe to access information published to one or more particular topics. For example, user 110a can subscribe to access information published to "NEWS/FINANCE". The notation '/' is used to indicate a path in the hierarchical information aggregate 120 from a root topic in the hierarchy in order to uniquely identify a particular topic in the hierarchy. Thus, "NEWS/FINANCE" uniquely identifies topic "FINANCE" 124 in the hierarchy. For example, if user 110a is subscribed to access information published to "NEWS/FINANCE", the user 110a is able to access any information published by the information provider 102 to the topic "FINANCE" 124. Similarly a user can subscribe to a branch of the hierarchical information aggregate 120 using a wildcard. For example, user 110b can subscribe to access information published to "NEWS/FINANCE/#", where the notation '#' is used to indicate a wildcard subscription to all topics descending from the topic "FINANCE" 124. Thus, if user 110b subscribes to "NEWS/FINANCE/#" the user 110b is able to access any information published to any of the topics "FINANCE" 124, "BUSINESS" 128 and "PERSONAL" 130. The hierarchical information aggregate 120 is illustrated as having five topics, although it will be apparent to those skilled in the art that any number of topics could constitute the hierarchical information aggregate 120.

[058] Figure 1c is an illustrative example of the topic key hierarchy 144 of Figure 1a. The topic key hierarchy 144 includes a topic key for association with each of the topics 122

to 130 in the hierarchical information aggregate 120. A topic key K_A 132 is associated with the topic "NEWS" 122. A topic key K_B 134 is associated with the topic "FINANCE" 124 and so on. The topic keys K_A 132, K_B 134, K_C 136, K_D 138 and K_E 140 are encryption keys generated by the topic key generator 106. For example, where the topic key generator 106 is a public/private key generator, the topic keys 144 include a public key and a private key for each topic in the hierarchical information aggregate 120. Information published to a topic in the hierarchical information aggregate 120 is encrypted by the encrypter 150 of the information provider 102 using a topic key associated with the topic. Whilst the topic key hierarchy 144 is illustrated as residing within the information provider 102 and being separate from the hierarchical information aggregate 120 it will be appreciated by those skilled in the art that the topic key hierarchy 144 can be integrated into the hierarchical information aggregate 120 and can be stored remotely from the information provider 102. For example, the hierarchical information aggregate 120 can include a hierarchy of topics with a topic key associated with each topic within the hierarchy.

[059] Figure 1d is an illustrative example of the logical key hierarchy 112 of Figure 1a as is known in the art. Logical key hierarchies are described in detail in the paper "Secure Group Communications Using Key Graphs" (Wong et al, IEEE/ACM Transactions on Networking, Vol. 8, No. 1, Feb 2000 pp. 16-30). The logical key hierarchy 112 is a logical tree structure of encryption keys A 114a, A1 116a and A2 118a. In the logical key hierarchy 112 an indication for each of the users 110a and 110b of the multicast audience 108 is associated with a 'leaf' key in the logical tree structure. That is to say an indicator 140a for user 110a is associated with key A1 116a at a leaf of the logical key hierarchy 112. Similarly, an indicator 140b for user 110b is associated with key A2 118a at a leaf of the logical key hierarchy 112. All users in the multicast audience 108 will be associated with leaf keys in the logical key hierarchy 112 in this way. The arrangement of keys in the logical key hierarchy 112 is configured for a particular multicast audience 108 to accommodate a most effective or efficient distribution of keys about the multicast audience 108 for a particular multicast distribution system as is known in the art and from Wong et al.. Particular methods and considerations for the design of the logical key hierarchy 112 are outside the scope of this description and will not be included here.

[060] Each of the users 110a and 110b has access to keys corresponding to each of the keys in the path from the user's associated leaf key to the root of the logical key hierarchy 112. Considering first user 110a, Figure 1e is an illustrative example of user 110a which is associated with key A1 116a in the logical key hierarchy 112 by way of the indicator 140a of Figure 1d. User 110a has access to keys corresponding to each of keys A1 116a and A 114a because these keys are in the path from its associated leaf

key to the root. User 110a therefore has access to key A1 116b which corresponds to key A1 116a in the logical key hierarchy 112. User 110a also therefore has access to key A 114b which corresponds to key A 114a in the logical key hierarchy 112. Keys A1 116b and A 114b can be copies of the corresponding keys A1 116a and A 114a. Alternatively, public/private key encryption can be employed where keys A1 116b and A 114b are private keys for decryption and keys A1 116a and A 114a are public keys for encryption. User 110a also includes a decrypter 156a which is a hardware or software device or entity for generating a decrypted version of an encrypted data item using one or more decryption keys. For example, the decrypter 156a can use a private decryption key such as key A1 116b to decrypt an item of data. An example of a decrypter 156a is the "Pretty Good Privacy" (PGP) product. Considering now user 110b, Figure 1f is an illustrative example of user 110b which is associated with key A2 118a in the logical key hierarchy 112 by way of the indicator 140b of Figure 1d. User 110b has access to keys corresponding to each of keys A2 118a and A 114a because these keys are in the path from its associated leaf key to the root. Therefore, user 110b has access to key A2 118b which corresponds to key A2 118a in the logical key hierarchy 112. User 110b also therefore has access to key A 114b which corresponds to key A 114a in the logical key hierarchy 112. Keys A2 118b and A 114b can be copies of the corresponding keys A2 118a and A 114a. Alternatively, public/private key encryption can be employed where keys A2 118b and A 114b are private keys for decryption and keys A2 118a and A 114a are public keys for encryption. User 110a also includes a decrypter 156b which is equivalent to the decrypter 156a of user 110a. It should be noted that in this example both users 110a and 110b have access to key A 114b corresponding to key A 114a in the logical key hierarchy. Thus, data encrypted by the information provider 102 using Key A 114a can be decrypted by both users 110a and 110b.

The logical key hierarchy 112 is illustrated as having three keys, although it will be apparent to those skilled in the art that any number of keys can be organised in a logical key hierarchy 112.

Figure 2 is a flow chart illustrating a method for publishing information in a multicast system. When one of the publishers 148a and 148b publishes information to a topic of the hierarchical information aggregate 120, the information provider 102 employs the method of Figure 2 to multicast the information as a multicast message to the multicast audience 108. Initially at step 202 the information provider 102 determines a subset of all users in the multicast audience 108 which are subscribed to the topic to which information is published. This determination is made with reference to the user subscription data 104. Subsequently, at step 204, the published information is encrypted as a multicast message by the encrypter 150 using a topic key in the topic

key hierarchy 144. The topic key used for the encryption is a key associated with the topic to which the published information is published in the hierarchical information aggregate 120. At step 206 the topic key is itself encrypted for the subscribed users using the logical key hierarchy 112. Thus, the topic key is encrypted one or more times using keys from the logical key hierarchy 112 so that only users subscribed to the topic to which the published information is published are able to decrypt the topic key, as is well known in the art. This technique is described in detail in Wong et al. Finally, at step 208, the encrypted topic key and the encrypted multicast message are communicated by the multicaster 152 to the multicast audience 108. In this way the published information is encrypted using a topic key for an appropriate topic without the need for the generation of a random key for the multicast message. Also, using this method the topic key is distributed to subscribed users so that only users subscribed to the topic to which information is published can access the multicast message.

[063] In addition to the method of Figure 2 for publishing information in a multicast system a topic key is generated in the topic key hierarchy 144 for each of the topics 122 to 130 in the hierarchical information aggregate 120. The generation of a topic key in the topic key hierarchy 144 can be undertaken when a topic is first defined in the hierarchical information aggregate. For example, a topic key can be generated when information is first published to a new topic by a publisher 148a or 148b. The generated topic key can then be encrypted one or more times using keys from the logical key hierarchy 114 and communicated to the multicast audience 108 along with a multicast message containing published information as described at step 208 of Figure 2. Alternatively, the generated topic key can be encrypted using the logical key hierarchy 112 and communicated to the multicast audience 108 in a separate multicast message, such as a multicast message which does not contain published information. Thus the use of a random key for each multicast message is avoided.

[064] It is preferable to regenerate a topic key for a topic when the user subscription data 104 is updated to add or remove a subscribed user to the topic. A topic key is regenerated by discarding the topic key and generating a new topic key using the topic key generator 106. The regeneration of a topic key is preferable to prevent a newly subscribed user from decrypting previously transmitted multicast messages. Further, the regeneration of a topic key is preferable to prevent a newly unsubscribed user from continuing to decrypt future multicast messages. Figure 3 is a flow chart illustrating a method for regenerating topic keys. The method is responsive to a change to the user subscription data 104 at step 302. In response to a change to user subscription data 104 for one or more topics in the hierarchical information aggregate 120, step 304 regenerates a topic key for each affected topic in the topic key hierarchy 144 using the topic key generator 106. In this way a topic key in the topic key hierarchy 144 is only

regenerated when a new user subscribes to, or a subscribed user unsubscribes from, the corresponding topic.

[065] The methods described above will now be considered in use, by way of example only, for a situation where user 110a subscribes to topic "PERSONAL" 130 in the hierarchical information aggregate 120. In order to subscribe to topic "PERSONAL" 130 the user 110a communicates a request to the information provider 102 for subscription to "NEWS/FINANCE/PERSONAL". This request results in a change to the user subscription data 104. Considering the method of Figure 3 for regenerating topic keys, at step 302 the method responds to the addition of user 110a as a subscriber to topic "PERSONAL" 130 in the user subscription data 104. Subsequently at step 304 a new topic key K_E 140 for topic "PERSONAL" 130 is generated using topic key generator 106. Thus, when the user subscription data 104 changes for topic "PERSONAL" 130 the topic key K_E 140 is regenerated.

[066] In a second example, user 110b communicates a request to the information provider 102 for subscription to "NEWS/FINANCE/#". This request results in a change to the user subscription data 104 to include user 110b as a subscriber to topics "FINANCE" 124, "BUSINESS" 128 and "PERSONAL" 130. Considering the method of Figure 3 for regenerating topic keys, at step 302 the method responds to the addition of user 110b as a subscriber to topics "FINANCE" 124, "BUSINESS" 128 and "PERSONAL" 130 in the user subscription data 104. Subsequently at step 304 new topic keys are generated for the affected topics "FINANCE" 124, "BUSINESS" 128 and "PERSONAL" 130 in the topic key hierarchy 144. This results in the regeneration of topic keys K_B 134, K_D 138 and K_E 140 using topic key generator 106. Thus, when the user 110b subscribes to "NEWS/FINANCE/#", subscription data 104 changes for topics "FINANCE" 124, "BUSINESS" 128 and "PERSONAL" 130, and the corresponding topic keys are regenerated.

[067] The method of Figure 2 will now be considered in use for the situation where user 110b is the only user subscribed to topic "FINANCE" 124 and information is published to topic "FINANCE" 124 by one of the publishers 148a or 148b. At step 202 the information provider 102 determines that user 110b is subscribed to topic "FINANCE" 124 with reference to the user subscription data 104. At step 204 the encrypter 150 encrypts information published to topic "FINANCE" 124 as a multicast message using the topic key K_B 134 which corresponds to the topic "FINANCE" 124 in the topic key hierarchy 144. Subsequently, at step 206, the encrypter 150 encrypts the topic key K_B 134 for the subscribed user 110b using the logical key hierarchy 112. This involves using key A2 118a in the logical key hierarchy 112 since this key corresponds to user 110b which is the only user subscribed to topic "FINANCE" 124 in the hierarchical information aggregate 120. Subsequently, at step 208, both the topic key K_B 134 as

encrypted using key A2 118a and the published information as encrypted using the topic key K_B 134 are communicated as a multicast message by the multicaster 152. The multicast message is received by both users 110a and 110b in the multicast audience 108. In this way, user 110b receives the topic key K_B 134 from the information provider 102. The user 110b is able to decrypt the topic key K_B 134 as user 110b has access to key A2 118b which corresponds to key A2 118a with which the topic key K_B 134 was encrypted. Once user 110b has decrypted the topic key K_B 134, user 110b is able to decrypt the published information which was encrypted using the topic key K_B 134. However, user 110a is unable to decrypt the topic key K_B 134 because user 110a does not have access to a key corresponding to key A2 118a in the logical key hierarchy 112. User 110a is therefore unable to access the published information encrypted using the topic key K_B 134. Thus the published information is only available to the subscribed user in the multicast audience 108, and the topic key K_B 134 for topic "FINANCE" 124 does not need to be regenerated for each publication of information to topic "FINANCE" 124.

[068] The method of Figure 2 will now be further considered in use for the situation where both users 110a and 110b are subscribed to topic "PERSONAL" 130 and information is published to topic "PERSONAL" 130 by one of the publishers 148a or 148b. At step 202 the information provider 102 determines that both users 110a and 110b are subscribed to topic "PERSONAL" 130 with reference to the user subscription data 104. At step 204 the encrypter 150 encrypts the information published to topic "PERSONAL" 130 as a multicast message using the topic key K_E 140 which corresponds to the topic "PERSONAL" 130 in the topic key hierarchy 144. Subsequently, at step 206, the encrypter 150 encrypts the topic key K_E 140 for both of the subscribed users 110a and 110b using the logical key hierarchy 112. Since both users are subscribed to the topic "PERSONAL" 130 a key from the logical key hierarchy 112 which is commonly accessible to both users 110a and 110b is selected to encrypt the topic key K_E 140. Key A 114b is commonly accessible to both users 110a and 110b, so corresponding key A 114a in the logical key hierarchy 112 can be used to encrypt the topic key K_E 140. Subsequently, at step 208, both the topic key K_E 140 as encrypted using key A 114a and the published information as encrypted using the topic key K_E 140 are communicated as a multicast message by the multicaster 152. The multicast message is received by both users 110a and 110b in the multicast audience 108. The user 110a is able to decrypt the topic key K_E 140 as user 110a has access to key A 114b which corresponds to key A 114a with which the topic key K_E 140 was encrypted. Once user 110a has decrypted the topic key K_E 140 user 110a is able to decrypt the published information which was encrypted using the topic key K_E 140. Similarly, the user 110b is able to decrypt the topic key K_E 140 as user 110b also has

access to key A 114b which corresponds to key A 114a with which the topic key K_E 140 was encrypted. Once user 110b has decrypted the topic key K_E 140 user 110b is able to decrypt the published information which was encrypted using the topic key K_E 140. Thus the published information is accessible by both subscribed users 110a and 110b in the multicast audience 108, and the topic key K_E 140 for topic "PERSONAL" 130 does not need to be regenerated for each publication of information to topic "PERSONAL" 130. Also, the use of the logical key hierarchy 112 to encrypt the topic key K_E 140 using the commonly accessible key A 114a renders is unnecessary to encrypt the topic key more than once.

[069] In addition to individual users subscribing to topics in the hierarchical information aggregate, the information provider may include an access control list defining topics which users are authorised to access. In such a system published information is secured so that it is only accessible to authorised users (as opposed to subscribed users), and users are only able to subscribe to topics which they are authorised to access in accordance with the access control list. In such an arrangement the generation and maintenance of a key for each topic can become burdensome because users will be authorised to access a collection of topics in an hierarchical information aggregate. In principle it would be beneficial to partition the hierarchical information aggregate into groups of topics in accordance with an access control list, and maintain a key for each such group of topics. A preferred embodiment of the present invention will now be described.

[070] Figure 4a is a schematic illustration of a multicast publish/subscribe system including a multicast information provider 402 in accordance with a preferred embodiment of the present invention. Many of the elements of Figure 4a are identical to those described with respect to Figure 1a and these will not be repeated here. The elements of Figure 4a which are not common with Figure 1a are described in detail below.

[071] The information provider 402 includes an access control list 460 defining topics in the hierarchical information aggregate 420 which users in the multicast audience 408 are authorised to access. The access control list 460 can be recorded in a database. Alternatively, the access control list 460 can be recorded in a memory of a computer system or as a file on a storage device of a computer system. It will be appreciated by those skilled in the art that other suitable means for storing the access control list 460 may be employed. The information provider 402 can use the access control list 460 to ensure that user subscriptions defined in the user subscription data 404 are consistent with the authorisations defined in the access control list 460. This is desirable so that a user is not able to subscribe to a topic that the user is not authorised to access.

[072] In one embodiment, the access control list 460 is defined as a list of topics or

branches in the hierarchical information aggregate 420 which a particular user is authorised to access. An example of such an access control list 460 will now be described with reference to an exemplary hierarchical information aggregate 420 illustrated in Figure 6a. The hierarchical information aggregate 420 of Figure 6a includes a root topic "FLIGHTS" 600. Descending from the root topic are topics "DOMESTIC" 602 and "INTERNATIONAL" 604. Descending from topic "DOMESTIC" 602 are topics "CENTRAL" 606, "EASTCOAST" 608 and "WESTCOAST" 610. Descending from topic "INTERNATIONAL" 604 are topics "EUROPE" 612 and "ASIA" 614. Based on this exemplary hierarchical information aggregate 420, Table 1 below is an access control list 460 for users 410a to 410d in one embodiment. For each of the users 410a to 410d, Table 1 includes a definition of a set of topics. Each user is only authorised to access information published to topics in the set of topics for that user in the access control list 460. For example, user 410a is authorised to access information published to {FLIGHTS/DOMESTIC/#}. Thus, user 410a is authorised to access information published to any of the topics "DOMESTIC" 602, "CENTRAL" 606, "EASTCOAST" 608 and "WESTCOAST" 610 as these are the topics belonging to the set {FLIGHTS/DOMESTIC/#}.

USER	AUTHORISED TOPICS
User 410a	{FLIGHTS/DOMESTIC/#}
User 410b	{FLIGHTS/INTERNATIONAL/#, FLIGHTS/DOMESTIC/WESTCOAST}
User 410c	{FLIGHTS/DOMESTIC/#, FLIGHTS/INTERNATIONAL/EUROPE}
User 410d	{FLIGHTS/DOMESTIC/#}

[073] **Table 1 - Access Control List 460**

[074] Figure 4b illustrates an alternative embodiment of the access control list 460. The access control list of Figure 4b includes roles 4602 and users 4604. Roles 4602 contains one or more named sets of topics or branches of the hierarchical information aggregate 420. Users 4604 contains an entry for each of users 410a to 410d and specifies, for each user, which of the roles 4602 the user is associated with. A user associated with a role is only authorised to access information published to topics in that role. An example of such an access control list 460 will now be described with reference to the hierarchical information aggregate 420 of Figure 6a. Table 2a below is an example definition of the roles 4602 of Figure 4b. Each row in Table 2a is a named set of topics of the hierarchical information aggregate 420.

ROLE NAME	AUTHORISED TOPICS
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PACIFIC 622	{FLIGHTS/INTERNATIONAL/#, FLIGHTS/ DOMESTIC/WESTCOAST}
DOMESTIC 624	{FLIGHTS/DOMESTIC/#}
DOMESTIC-EURO 626	{FLIGHTS/DOMESTIC/#, FLIGHTS/IN- TERNATIONAL/EUROPE}
ALL 628	{FLIGHTS/#}

[075] **Table 2a - Roles 4602**

[076] Thus, for example, the role "DOMESTIC" 624 includes the set of topics {FLIGHTS/DOMESTIC/#} in the hierarchical information aggregate 420. Thus, the role "DOMESTIC" 624 corresponds to the topics "DOMESTIC" 602, "CENTRAL" 606, "EASTCOAST" 608 and "WESTCOAST" 610. Table 2b below is an example definition of users 4604 of Figure 4b. Each row in Table 2b corresponds to one of the users 410a to 410d of the multicast audience 408.

USER	ROLE
User 410a	DOMESTIC 624
User 410b	PACIFIC 622
User 410c	DOMESTIC-EURO 626
User 410d	DOMESTIC 624

[077] **Table 2b - Users 4604**

[078] Thus, for example, the user 410a is specified as belonging to the role "DOMESTIC" 624. The user 410a is therefore only authorised to access information published to topics included in the role "DOMESTIC" 624. As considered above, the role "DOMESTIC" 642 includes the set of topics {FLIGHTS/DOMESTIC/#}. Thus, user 410a is only authorised to access information published to the topics "DOMESTIC" 602, "CENTRAL" 606, "EASTCOAST" 608 and "WESTCOAST" 610.

[079] In these ways it is possible to control individual user's access to information published to individual topics in the hierarchical information aggregate 420. Each of the two example embodiments of the access control list 460 described above includes a definition of sets of topics or branches to which information can be published that users are authorised to access. It will be appreciated by those skilled in the art that an access control list 460 could equally include a definition of sets of topics or branches to which information can be published that users are not authorised to access (i.e. exclusions to authorisation). Furthermore, while two example embodiments of the access control list 460 have been described above, it will be appreciated by those

skilled in the art that any suitable mechanism for specifying access controls for users in the multicast audience 408 may be employed.

- [080] Returning now to Figure 4a, the information provider 402 further includes an information aggregate partitioner 462. The information aggregate partitioner 462 partitions the hierarchical information aggregate 420 into one or more partition elements 468. Each of the partition elements 468 is defined mathematically as a disjoint proper subset of topics from the hierarchical information aggregate 420. Disjoint proper subsets are well known in set theory and can be defined, for an hierarchical information aggregate T , as a collection of sets, $S_1, S_2, S_3 \dots S_n$ of the topics of T where, for any two sets, S_i, S_j :
- [081] $(S_i \cap S_j = \emptyset)$ and $(S_1 \cup S_2 \cup S_3 \dots \cup S_n = T)$
- [082] Thus no two of the sets $S_1, S_2, S_3 \dots S_n$ intersect, and the union of all the sets is exactly equal to the whole hierarchical information aggregate T . The partition elements 468 are defined using the access control list 460 to partition the hierarchical information aggregate 420. Each of the partition elements 468 represents a building block of the access control list 460. For example, each of the roles 4602 can be defined in terms of a discrete list of partition elements. The purpose of the partition elements is to define an appropriate grouping of topics in the hierarchical information aggregate 420 so that encryption keys can be assigned to groups of topics so avoiding any need to generate a key for every topic in the hierarchy.
- [083] A method for defining the partition elements 468 is provided in Figure 5a, and will be now considered with reference to the hierarchical information aggregate 420 of Figure 6a and the access control list 460 defined in Tables 2a and 2b above.
- [084] Considering first step 502 of the method of Figure 5a, subsets of the hierarchical information aggregate 420 are defined in accordance with the access control list 460. To illustrate this in practice, Figure 6b depicts the hierarchical information aggregate of Figure 6a with the subsets defined in Table 2a of the access control list 460 indicated using bold lines. Table 2a defines four roles 4602, each role comprising a subset of the hierarchical information aggregate 420. It can be seen from Figure 6b that the role "PACIFIC" 622 defines a subset which includes the topics "INTERNATIONAL" 604, "WESTCOAST" 610, "EUROPE" 612 and "ASIA" 614. Also, the role "DOMESTIC" 624 defines a subset of the hierarchical information aggregate which includes the topics "DOMESTIC" 602, "CENTRAL" 606, "EASTCOAST" 608, "WESTCOAST" 610. Similarly, the roles "DOMESTIC-EURO" 626 and "ALL" 628 define subsets of the hierarchical information aggregate 420. It can also be seen that the subsets defined by the roles 4602 intersect each other and so do not, at this stage, form disjoint subsets.
- [085] Considering now step 504 of the method of Figure 5a, the subsets corresponding to the roles 4602 in the access control list 460 are used to partition the hierarchical in-

formation aggregate 420 into disjoint proper subsets. The disjoint proper subsets correspond to partition elements 468. Figure 6c illustrates the hierarchical information aggregate 420 partitioned into partition elements 468. Each element is a disjoint subset deriving from an intersect or set difference of the subsets of Figure 6b. A detailed method for generating a list of disjoint subsets is considered below with respect to Figures 5b and 5c. There are five partition elements 468: partition element "L" 4680; partition element "M" 4682; partition element "N" 4684; partition element "O" 4686; and partition element "P" 4688. Table 3 below provides a definition of each of the partition elements 468 using set notation following the method of Figure 5a.

PARTITION ELEMENT	PARTITION ELEMENT DEFINITION
Partition element "L" 4680	{FLIGHTS}
Partition element "M" 4682	{FLIGHTS/DOMESTIC, FLIGHTS/DOMESTIC/CENTRAL, FLIGHTS/DOMESTIC/EASTCOAST}
Partition element "N" 4684	{FLIGHTS/DOMESTIC/WESTCOAST}
Partition element "O" 4686	{FLIGHTS/INTERNATIONAL/EUROPE}
Partition element "P" 4688	{FLIGHTS/INTERNATIONAL, FLIGHTS/INTERNATIONAL/ASIA}

[086] **Table 3 - Partition Elements 468**

[087] Thus it can be seen that the partition elements "L" 4680 to "P" 4688 are disjoint proper subsets of the hierarchical information aggregate 420 as no two partition elements intersect and the union of all partition elements contains all topics in the hierarchical information aggregate 420. It is desirable for the information aggregate partitioner 462 to generate the partition elements 468 whenever the access control list 460 is changed. This ensures that the partition elements 468 accurately reflect the access control list 460.

[088] Figure 5b is a flowchart illustrating a method for generating a list of disjoint subsets from a list of subsets in a preferred embodiment of the present invention. For example, the method of Figure 5b can be used to generate a list of disjoint subsets of topics in the hierarchical information hierarchy 420 from a list of roles, where each role defines a subset of the hierarchy. The method of Figure 5b will now be described in use with reference to a further, simpler, example of the hierarchical information aggregate 420 illustrated in Figure 5c. The hierarchical information aggregate 420 of Figure 5c includes seven topics 550 to 560 arranged such that topic 550 is the root of the hierarchy. Topics 552 and 553 descend from topic 550. Topics 554 and 556 descend from topic 552, and topics 558 and 560 descend from topic 553. Figure 5c further il-

illustrates three subsets of the hierarchical information aggregate 420, such as roles 4602 of an access control list 460. A first subset I 570 includes all topics 552 to 560. A second subset j 572 includes topics 552, 554 and 556. A third subset k 574 includes topics 553, 558 and 560. A list of all subsets is summarised in Table 4a below for convenience.

SUBSET	SUBSET DEFINITION
Subset i 570	{550, 552, 553, 554, 556, 558, 560}
Subset j 572	{552, 554, 556}
Subset k 574	{554, 556, 558, 560}

[089] **Table 4a - List of All Subsets (of Figure 5c)**

Considering now the method of Figure 5b in use, at step 510 all combinations of pairs of subsets from the list of subsets in Table 4a above is determined. This, with the three subsets I 570, j 572 and K 574, all combinations of pairs subsets can be summarised as outlined in Table 4b below. Each pair of subsets is specified in parentheses using the subset name.

Combination 1	(i, j)
Combination 2	(i, k)
Combination 3	(j, k)

[090] **Table 4b - All Combinations of Subsets**

[091] Subsequently, at step 512, a loop is initiated through all combinations of pairs of subsets. Starting at combination 1 (i, j), step 514 determines if $(i \cap j \neq \emptyset)$. Using the definitions of subsets i 570 and j 572 in table 4a, it can be seen that:

[092] $i \cap j = \{552, 554, 556\}$

[093] and thus it is true that $(i \cap j \neq \emptyset)$ and the method proceeds to step 516. At step 516, a new subset is added to the list of all subsets (we shall call it subset l), where the new subset corresponds to $(i \cap j)$. Thus, new subset l is defined as $\{552, 554, 556\}$. Further, at step 518, a new subset is added to the list of all subsets (we shall call it subset m), where the new subset corresponds to $(i - j)$. Thus, new subset m is defined as $\{550, 553, 558, 560\}$. Further, at step 520, a new subset is added to the list of all subsets (we shall call it subset n), where the new subset corresponds to $(j - i)$. Thus, new subset n is defined as $\{552, 554, 556\}$. Thus, steps 516 to 520 result in the three new subsets l, m and n being added to the list of subsets in Table 4a. At step 522, the subsets i 570 and j 572 are removed from the list of all subsets. Thus, at this step, the list of all subsets is as defined in Table 4c below.

SUBSET	SUBSET DEFINITION
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Subset k 574	{554, 556, 558, 560}
Subset l	{552, 554, 556}
Subset m	{550, 553, 558, 560}
Subset n	{552, 554, 556}

[094] Subsequently, at step 524, duplicate subsets are removed from the list of all subsets. The list of all subsets includes subsets l and n which are both defined to be {552, 554, 556} and are thus duplicates. Subset n is therefore removed from the list of all subsets at step 524. At this step, the list of all subsets is as defined in Table 4d below.

SUBSET	SUBSET DEFINITION
Subset k 574	{554, 556, 558, 560}
Subset l	{552, 554, 556}
Subset m	{550, 553, 558, 560}

[095] **Table 4d - List of All Subsets**

[096] At step 526 all combinations of pairs of subsets is re-determined in the light of the new list of all subsets. Table 4e provides a new list of all combinations of pairs of subsets. The method then returns to step 512 to loop through a next pair of subsets.

Combination 1	(k, l)
Combination 2	(k, m)
Combination 3	(l, m)

[097] **Table 4e - All Combinations of Subsets**

[098] At step 512, a next pair of subsets is selected for processing from the list of combinations of pairs subsets. Since the list of combinations of pairs of subsets has been updated, the next pair of subsets for processing is the new first combination in the list, i.e. (k, l). Step 514 determines if $(k \cup l \neq \hat{A})$. Using the definitions of subsets k 574 and l in table 4d, it can be seen that:

[099] $k \cup l = \{554, 556\}$

[100] and thus it is true that $(k \cup l \neq \hat{A})$ and the method proceeds to step 516. At step 516, a new subset is added to the list of all subsets (we shall call it subset o), where the new subset corresponds to $(k \cup l)$. Thus, new subset o is defined as {554, 556}. Further, at step 518, a new subset is added to the list of all subsets (we shall call it subset p), where the new subset corresponds to $(k - l)$. Thus, new subset p is defined as {558, 560}. Further, at step 520, a new subset is added to the list of all subsets (we shall call it subset q), where the new subset corresponds to $(l - k)$. Thus, new subset q is defined

as {552}. Thus, steps 516 to 520 result in the three new subsets o, p and q being added to the list of subsets in Table 4d. At step 522, the subset k 574 and subset l are removed from the list of all subsets. Thus, at this step, the list of all subsets is as defined in Table 4c below.

SUBSET	SUBSET DEFINITION
Subset m	{550, 553, 558, 560}
Subset o	{554, 556}
Subset p	{558, 560}
Subset q	{552}

[101] **Table 4f - List of All Subsets**

[102] Subsequently, at step 524, duplicate subsets are removed from the list of all subsets. The list of all subsets does not include any duplicates so the method proceeds to step 526 where all combinations of pairs of subsets is re-determined in the light of the new list of all subsets. Table 4g provides a new list of all combinations of pairs of subsets. The method then returns to step 512 to loop through a next pair of subsets.

Combination 1	(m, o)
Combination 2	(m, p)
Combination 3	(m, q)
Combination 4	(o, p)
Combination 5	(o, q)
Combination 6	(p, q)

[103] **Table 4g - All Combinations of Subsets**

[104] At step 512, a next pair of subsets is selected for processing from the list of combinations of pairs subsets. Since the list of combinations of pairs of subsets has been updated, the next pair of subsets for processing is the new first combination in the list, i.e. (m, o). Step 514 determines if $(m \cap o \neq \emptyset)$. Using the definitions of subsets m and o in table 4f, it can be seen that:

[105] $m \cap o = \{ \} = \emptyset$

[106] and thus $(m \cap o \neq \emptyset)$ is false. The method consequently proceeds to step 528 where it is determined that there are more combinations of pairs of subsets to be processed. Processing returns to step 512 for a next pair of subsets, (m, p). Step 514 determines if $(m \cap p \neq \emptyset)$. Using the definitions of subsets m and p in table 4f, it can be seen that:

[107] $m \cap p = \{558, 560\}$

[108] and thus it is true that $(m \cap p \neq \emptyset)$ and the method proceeds to step 516. At step

516, a new subset is added to the list of all subsets (we shall call it subset r), where the new subset corresponds to $(m \cup p)$. Thus, new subset r is defined as {558, 560}. Further, at step 518, a new subset is added to the list of all subsets (we shall call it subset s), where the new subset corresponds to $(m - p)$. Thus, new subset s is defined as {550, 553}. Further, at step 520, a new subset is added to the list of all subsets (we shall call it subset t), where the new subset corresponds to $(p - m)$. Thus, new subset t is defined as $\{\}$. Subset t is an empty set and is therefore not added to the list of all subsets. Thus, steps 516 to 520 result in the two new subsets r and s being added to the list of subsets in Table 4f. At step 522, the subset m and subset p are removed from the list of all subsets. Thus, at this step, the list of all subsets is as defined in Table 4h below.

SUBSET	SUBSET DEFINITION
Subset o	{554, 556}
Subset q	{552}
Subset r	{558, 560}
Subset s	{550, 553}

[109] **Table 4h - List of All Subsets**

[110] Subsequently, at step 524, duplicate subsets are removed from the list of all subsets. The list of all subsets does not include any duplicates so the method proceeds to step 526 where all combinations of pairs of subsets is re-determined in the light of the new list of all subsets. Table 4i provides a new list of all combinations of pairs of subsets. The method then returns to step 512 to loop through a next pair of subsets.

Combination 1	(o, q)
Combination 2	(o, r)
Combination 3	(o, s)
Combination 4	(q, r)
Combination 5	(q, s)
Combination 6	(r, s)

[111] **Table 4i - All Combinations of Subsets**

[112] At step 512, a next pair of subsets is selected for processing from the list of combinations of pairs subsets. Since the list of combinations of pairs of subsets has been updated, the next pair of subsets for processing is the new first combination in the list, i.e. (o, q). Step 514 determines if $(o \cup q \supseteq \hat{A})$. Using the definitions of subsets o and q in table 4h, it can be seen that:

[113] $o \cap q = \{\} = \hat{A}$

[114] and thus $(o \cap q \cap \hat{A})$ is false. The method consequently proceeds to step 528 where it is determined that there are more combinations of pairs of subsets to be processed. Processing returns to step 512 for a next pair of subsets, (o, r) . Step 514 determines if $(o \cap r \cap \hat{A})$. Using the definitions of subsets o and r in table 4h, it can be seen that:

[115] $o \cap r = \{\} = \hat{A}$

[116] and thus $(o \cap r \cap \hat{A})$ is false. The method proceeds in this way processing all combinations of pairs of subsets finding that each combination does not intersect. Once all combinations are processed, step 528 then terminates the method.

[117] Thus the method of Figure 5b generates the list of all subsets in Table 4h which is a list of disjoint proper subsets. It is these disjoint proper subsets which correspond to partition elements in a preferred embodiment of the present invention. Figure 5d illustrates the disjoint proper subsets generated using the method of Figure 5b.

[118] Returning now to Figure 4a, the information provider 402 further includes a partition element key generator 470. The partition element key generator 470 is a hardware or software device or entity for generating partition element keys 472. Partition element keys 472 are encryption keys, such as public keys and private keys required for public/private key encryption. Each of the partition element keys 472 corresponds to one of the partition elements 468. An example of a partition element key generator 470 is the "Pretty Good Privacy" (PGP) product (Pretty Good Privacy and PGP are registered trademarks of PGP Corporation). Table 6 below illustrates the partition element keys 472 for the partition elements 468 defined above with respect to Figure 6c and Table 3.

PARTITION ELEMENT	PARTITION ELEMENT KEY
Partition element "L" 4680	Key K_L 4720
Partition element "M" 4682	Key K_M 4722
Partition element "N" 4684	Key K_N 4724
Partition element "O" 4686	Key K_O 4726
Partition element "P" 4688	Key K_P 4728

[119] **Table 5 - Partition Element Keys 472**

[120] Thus a partition element key K_L 4720 is associated with the partition element "L" 4680. A partition element key K_M 4722 is associated with the partition element "M" 4682 and so on. The partition element key generator 470 generates the partition element keys 472 when the partition elements 468 are first created by the information aggregate partitioner 462. Alternatively, a partition element key can be generated for a particular partition element when a first user subscribes to a topic in the partition

element. This has the advantage of avoiding the generation of keys for a partition element when no user subscribes to any of the topics in the partition element. Additionally, changes to the access control list 460 may result in changes to the partition elements 468. When one of the partition element 468 changes (such as through the inclusion of addition topics into a partition element, or a exclusion of topics from a partition element) it is desirable to regenerate the corresponding partition element key 472. The regeneration of a partition element key is preferable to prevent a user who is newly authorised, through the access control list 460, to access information published to a particular topic from decrypting previously transmitted multicast messages. Further, the regeneration of a topic key is preferable to prevent users who is newly unauthorised, through the access control list 460, from continuing to decrypt future multicast messages.

[121] Returning to Figure 4a, the information provider 402 further includes a logical key hierarchy 412 equivalent to that of Figure 1a. In the preferred embodiment of the present invention the logical key hierarchy is used to securely communicate partition element keys 472 to authorised users in the multicast audience 408. Figure 7a is an illustrative example of the logical key hierarchy 412 of Figure 4a. The logical key hierarchy 412 is a logical tree structure of public encryption keys for use in public/private key encryption. A public key F 41202a is at the root of the logical key hierarchy 412. Directly descending from public key F 41202a are public keys F1 41204a and F2 41206a. Directly descending from public key F1 41204a are public keys F11 41208a and F12 41210a. Directly descending from public key F12 41210a are public keys F121 41212a and F122 41214a. The logical key hierarchy 412 includes an indicator for each of the users 410a to 410d. Each indicator is associated with a 'leaf' key in the logical tree structure. Indicator 480a corresponds to user 410a and is associated with public key F11 41208a. Indicator 480b corresponds to user 410b and is associated with public key F121 41212a, and so on.

[122] Each of the users 410a to 410d has access to private keys corresponding to each of the public keys in the path from the user's associated leaf key to the root of the logical key hierarchy 412. Considering first user 410a, Figure 7b is an illustrative example of user 410a which is associated with public key F11 41208a in the logical key hierarchy 112 by way of the indicator 480a of Figure 7a. User 410a has access to private keys corresponding to each of keys F 41202a, F1 41204a and F11 41208a because these keys are in the path from its associated leaf key to the root. User 410a therefore has access to: private key F 41202b corresponding to public key F 41202a; private key F1 41204b corresponding to public key F1 41204a; and private key F11 41208b corresponding to public key F11 41208a.

[123] User 410a also includes a decrypter 4102a which is a hardware or software device

or entity for generating a decrypted version of an encrypted data item using one or more decryption keys. For example, the decrypter 4120a can use a private decryption key such as private key F11 41208b to decrypt an item of data. An example of a decrypter 4102a is the "Pretty Good Privacy" (PGP) product.

[124] Users 410b to 410d similarly have access to private keys corresponding to each of the public keys in the path from each user's associated leaf key to the root of the logical key hierarchy 412. Corresponding illustrations of users 410b to 410d are provided in Figures 7c to 7e. It should be noted that, in this exemplary embodiment, each of users 410a to 410d have access to private key F 41202b corresponding to public key F 41202a in the logical key hierarchy 412. Thus, data encrypted by the information provider 402 using public key F 41202a can be decrypted by all of users 410a to 410d. Similarly, other groups of users share common keys according to the logical key hierarchy 412. For example, users 410b and 410c both have access to private key F12 41210b, whilst no other user has access to private key F12 41210b. Thus, data encrypted by the information provider 402 using public key F12 41210a can only be decrypted by users 410b and 410c using corresponding private key F12 41210b. In this way the logical key hierarchy 412 can be used to distribute partition element keys 472 only to authorised users in the multicast audience 408.

[125] Figure 8 is a flow chart illustrating a method for publishing information in a multicast system in accordance with a preferred embodiment of the present invention. When one of the publishers 448a and 448b publishes information to a topic of the hierarchical information aggregate 420, the information provider 402 employs the method of Figure 8 to multicast the information as a multicast message to the multicast audience 408. Initially at step 802 the information provider 402 determines which one of the partition elements 468 contains the topic to which the information is published. The determined partition element will have associated a key from the partition element keys 472. Subsequently, at step 804, the published information is encrypted as a multicast message using the partition element key for the determined partition element. At step 806 the partition element key is itself encrypted for authorised users using a public key from logical key hierarchy 412. Thus, the partition element key is encrypted such that only users authorised to access information published to the topic are able to decrypt the partition element key. This technique of using a logical key hierarchy is well known in the art and is described in detail in Wong et al. Finally, at step 808, the encrypted partition element key and the encrypted multicast message are communicated by the multicaster 452 to the multicast audience 408. In this way the published information is encrypted using a partition element key corresponding to a partition element which contains the topic to which the information is published. Thus, there is no need for a separate key for each topic in the hierarchical information

aggregate 420.

- [126] The method of Figure 8 will now be considered in use for the configuration of the hierarchical information aggregate 420 defined in Figure 6a and the access control list 460 defined in Tables 2a and 2b above. The definition of partition elements 468 of Figure 6c and Table 3 will also apply. Three scenarios will be considered in which information is published by publishers 448a and 448b. The three scenarios are outlined in Table 6 below.

SCENARIO	PUBLISHER	TOPIC
Scenario 1	Publisher 448a	"EUROPE" 612
Scenario 2	Publisher 448b	"WESTCOAST" 610
Scenario 3	Publisher 448a	"ASIA" 614

[127] **Table 6 - Scenarios**

- [128] Considering first the method of Figure 8 for scenario 1. In scenario 1 publisher 448a publishes information to topic "EUROPE" 612. Initially at step 802 the information provider 402 determines which one of the partition elements 468 contains the topic to which the information is published. Referring to the definition of the partition elements in Table 3 the information provider 402 can determine that the topic "EUROPE" 612 resides in partition element "O" 4686. Further, from Table 5, partition element "O" 4686 has associated partition element key K_o 4726. Subsequently, at step 804, the published information is encrypted as a multicast message using partition element key K_o 4726. At step 806 the partition element key K_o 4726 is itself encrypted for authorised users using a public key from logical key hierarchy 412. The information provider 402 can determine which users are authorised to access information published to the topic "EUROPE" 612 with reference to the access control list 460 defined in Tables 2a and 2b. From Table 2a it can be seen that topic "EUROPE" 612 is included in the role "PACIFIC" 622 (by way of "FLIGHTS/INTERNATIONAL/#"), the role "DOMESTIC-EURO" 626 (by way of "FLIGHTS/INTERNATIONAL/EUROPE") and the role "ALL" 628 (by way of "FLIGHTS/#"). Thus, users belonging to these roles are authorised to access information published to the topic "EUROPE" 612. From Table 2b it can be seen that user 410b is a member of the role "PACIFIC" 622, and user 410c is a member of the role "DOMESTIC-EURO" 626. Thus, users 410b and 410c are authorised to access information published to the topic "EUROPE" 612. So, at step 806, a key from the logical key hierarchy 412 which is accessible to only users 410b and 410c is selected to encrypt the partition element key K_o 4726. From Figures 7a to 7e it can be seen that public key F12 41210a is appropriate, as only users 410b and 410c have a corresponding private key F12 41210b. Partition element key K_o 4726

is therefore encrypted by the information provider 402 using the public key F12 41210a. Finally, at step 808, the encrypted partition element key K_o 4726 and the encrypted multicast message are communicated by the multicaster 452 to the multicast audience 408. In this way, the encrypted partition element key K_o 4726 is only accessible to authorised users 410b and 410c, and thus only these users can decrypt the multicast message containing the published information.

[129] Considering next the method of Figure 8 for scenario 2. In scenario 2 publisher 448b publishes information to topic "WESTCOAST" 610. Initially at step 802 the information provider 402 determines which one of the partition elements 468 contains the topic to which the information is published. Referring to the definition of the partition elements in Table 3 the information provider 402 can determine that the topic "WESTCOAST" 610 resides in partition element "N" 4684. Further, from Table 5, partition element "N" 4684 has associated partition element key K_N 4724. Subsequently, at step 804, the published information is encrypted as a multicast message using partition element key K_N 4724. At step 806 the partition element key K_N 4724 is itself encrypted for authorised users using a public key from logical key hierarchy 412. The information provider 402 can determine which users are authorised to access information published to the topic "WESTCOAST" 610 with reference to the access control list 460 defined in Tables 2a and 2b. From Table 2a it can be seen that topic "WESTCOAST" 610 is included in the role "PACIFIC" 622 (by way of "FLIGHTS/DOMESTIC/WESTCOAST"), the role "DOMESTIC-EURO" 626 (by way of "FLIGHTS/DOMESTIC/#"), the role "DOMESTIC" 624 (by way of "FLIGHTS/DOMESTIC/#") and the role "ALL" 628 (by way of "FLIGHTS/#"). Thus, users belonging to these roles are authorised to access information published to the topic "WESTCOAST" 610. From Table 2b it can be seen that user 410a is a member of the role "DOMESTIC" 624, user 410b is a member of the role "PACIFIC" 624 and user 410c is a member of the role "DOMESTIC-EURO" 626. Thus, users 410a, 410b and 410c are authorised to access information published to the topic "WESTCOAST" 610. So, at step 806, a key from the logical key hierarchy 412 which is accessible to only users 410a, 410b and 410c is selected to encrypt the partition element key K_N 4724. From Figures 7a to 7e it can be seen that public key F1 41204a is appropriate, as only users 410a, 410b and 410c have a corresponding private key F1 41204b. Partition element key K_N 4724 is therefore encrypted by the information provider 402 using the public key F1 41204a. Finally, at step 808, the encrypted partition element key K_N 4724 and the encrypted multicast message are communicated by the multicaster 452 to the multicast audience 408. In this way, the encrypted partition element key K_N 4724 is only accessible to authorised users 410a, 410b and 410c, and thus only these users can decrypt the multicast message containing the published information.

[130] Considering next the method of Figure 8 for scenario 3. In scenario 3 publisher 448a publishes information to topic "ASIA" 614. Initially at step 802 the information provider 402 determines which one of the partition elements 468 contains the topic to which the information is published. Referring to the definition of the partition elements in Table 3 the information provider 402 can determine that the topic "ASIA" 614 resides in partition element "P" 4688. Further, from Table 5, partition element "P" 4688 has associated partition element key K_p 4728. Subsequently, at step 804, the published information is encrypted as a multicast message using partition element key K_p 4728. At step 806 the partition element key K_p 4728 is itself encrypted for authorised users using a public key from logical key hierarchy 412. The information provider 402 can determine which users are authorised to access information published to the topic "ASIA" 614 with reference to the access control list 460 defined in Tables 2a and 2b. From Table 2a it can be seen that topic "ASIA" 614 is included in the role "PACIFIC" 622 (by way of "FLIGHTS/INTERNATIONAL/#") and the role "ALL" 628 (by way of "FLIGHTS/#"). Thus, users belonging to these roles are authorised to access information published to the topic "ASIA" 614. From Table 2b it can be seen that user 410b is a member of the role "PACIFIC" 622. Thus, user 410b is authorised to access information published to the topic "ASIA" 614. So, at step 806, a key from the logical key hierarchy 412 which is accessible to only user 410b is selected to encrypt the partition element key K_p 4728. From Figures 7a to 7e it can be seen that public key F121 41212a is appropriate, as only user 410b has a corresponding private key F121 41212b. Partition element key K_p 4728 is therefore encrypted by the information provider 402 using the public key F121 41212a. Finally, at step 808, the encrypted partition element key K_p 4728 and the encrypted multicast message are communicated by the multicaster 452 to the multicast audience 408. In this way, the encrypted partition element key K_p 4728 is only accessible to authorised user 410b and thus only this user can decrypt the multicast message containing the published information.

[131] Thus, where an access control list 460 is provided, keys can be assigned to groups of topics as partition elements 468 rather than to each individual topic. In this way it is not necessary to assign a key to each topic unless the granularity of access control requires it (i.e. unless access control is defined on a per-topic basis).

CLAIMS

1. A multicast host for communicating information published about any one of a set of topics in a hierarchical information aggregate to one or more authorized subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the multicast host comprising:

a memory, wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to:

receive information relating to a topic;

determine a partition element for the topic;

retrieve a partition element encryption key associated with the partition element;

encrypt the information with the retrieved partition element encryption key; and

communicate the information to the one or more authorized subscribers by securely communicating the partition element encryption key to the one or more subscribers by encrypting the partition element encryption key using a logical key hierarchy in which a logical key corresponds to the one or more authorized subscribers and wherein each disjoint proper subset of the set of topics is defined in accordance with an access control list including a definition of a plurality of roles, wherein each of the plurality of roles is a subset of the set of topics.

2. The multicast host of claim 1 wherein each disjoint proper subset of the set of topics is defined to be one of a set difference and an intersect of the plurality of roles.

3. The multicast host of claim 1 wherein the memory further contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to securely communicate a partition element decryption key to the one or more authorized subscribers, wherein the partition element decryption key corresponds to the partition element encryption key and wherein the

partition element decryption key is securely communicated by encrypting the partition element decryption key using a logical key hierarchy in which a logical key corresponds to the one or more authorized subscribers.

4. The multicast host of claim 1 wherein the memory further contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to:

- receive a new subscription to a topic in a particular partition element; and
- generate a new partition element encryption key for the particular partition element.

5. The multicast host of claim 4 wherein the memory further contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to generate a new partition element decryption key corresponding to the new partition element encryption key.

6. The multicast host of claim 1 wherein the memory further contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to:

- receive a cancelled subscription to a topic in a particular partition element; and
- generate a new partition element encryption key for the particular partition element.

7. The multicast host of claim 6 wherein the memory further contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to generate a new partition element decryption key corresponding to the new partition element encryption key.

8. The multicast host of claim 1 wherein the one or more authorized subscribers is selected from a group of one or more multicast subscribers for receiving information communicated by the multicast host.

9. The multicast host of claim 1 wherein the information received is from one or more publishers for publishing information about any one of a plurality of topics.

10. A method for communicating information published about any one of a set of topics in a hierarchical information aggregate to one or more authorized subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the method comprising:

- receiving information relating to a particular topic in the set of topics ;
- determining a partition element for the particular topic;
- retrieving a partition element encryption key associated with the partition element;
- encrypting the information with the retrieved partition element encryption key; and
- communicating the information to the one or more authorized subscribers by securely communicating the partition element encryption key to the one or more subscribers by encrypting the partition element encryption key using a logical key hierarchy in which a logical key corresponds to the one or more authorized subscribers and wherein each disjoint proper subset of the set of topics is defined in accordance with an access control list including a definition of a plurality of roles, wherein each of the plurality of roles is a subset of the set of topics.

11. The method of claim 10 wherein each disjoint proper subset of the set of topics is defined to be one of a set difference and an intersect of the plurality of roles.

12. The method of claim 10 further comprising securely communicating a partition element decryption key to the one or more authorized subscribers, wherein the partition element decryption key corresponds to the partition element encryption key wherein the partition element decryption key is securely communicated by encrypting the partition element decryption key using a logical key hierarchy in which a logical key corresponds to the one or more authorized subscribers.

13. The method of claim 10 further comprising:
receiving a new subscription to a topic in a particular partition element; and
generating a new partition element encryption key for the particular partition element.
14. The method of claim 13 further generating a new partition element decryption key corresponding to the new partition element encryption key.
15. The method of claim 10 further comprising:
receiving a cancelled subscription to a topic in a particular partition element; and
generating a new partition element encryption key for the particular partition element.
16. The method of claim 15 further comprising generating a new partition element decryption key corresponding to the new partition element encryption key.
17. A computer program product having computer readable program means stored on a non-transitory computer usable medium, for communicating information published about any one of a set of topics in a hierarchical information aggregate to one or more authorized subscribers to those topics, the set of topics being partitioned into one or more partition elements, each partition element having a partition element encryption key associated therewith, wherein each of the one or more partition elements is a disjoint proper subset of the set of topics, the computer program product comprising:
computer readable program means for receiving information relating to a particular topic in the set of topics;
computer readable program means for determining a partition element for the particular topic;
computer readable program means for retrieving a partition element encryption key associated with the partition element;

computer readable program means for encrypting the information with the retrieved partition element encryption key; and

computer readable program means for communicating the information to the one or more authorized subscribers by securely communicating the partition element encryption key to the one or more subscribers by encrypting the partition element encryption key using a logical key hierarchy in which a logical key corresponds to the one or more authorized subscribers and wherein each disjoint proper subset of the set of topics is defined in accordance with an access control list including a definition of a plurality of roles, wherein each of the plurality of roles is a subset of the set of topics.

18. A multicast host for communicating information published about any one of a plurality of topics to subscribers to those topics, each topic having a topic encryption key associated therewith, the multicast host comprising:

a memory, wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, directs the multicast host to:

receive information relating to a particular topic;

access subscriber data representing one or more users subscribed to the particular topic;

retrieve a topic encryption key associated with the particular topic;

encrypt the information with the retrieved topic encryption key; and

communicate the information to the one or more users by securely communicating the topic encryption key to the one or more subscribers by encrypting the topic encryption key using a logical key hierarchy in which a logical key corresponds to the one or more users .

19. The multicast host of claim 18 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

securely communicate a topic decryption key to the one or more subscribers, wherein the topic decryption key corresponds to the topic encryption key and wherein the

topic decryption key is securely communicated by encrypting the topic decryption key using a logical key hierarchy in which a logical key corresponds to the one or more users.

20. The multicast host of claim 18 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

- receive a new subscription to a topic; and
- generate a new topic encryption key for the topic.

21. The multicast host of claim 20 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

- generate a new topic decryption key corresponding to the new topic encryption key.

22. The multicast host of claim 18 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

- receive information relating to a new topic; and
- generate a topic encryption key for the new topic.

23. The multicast host of claim 22 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

- generate a topic decryption key corresponding to the topic encryption key for the new topic.

24. The multicast host of claim 18 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

- receive a cancelled subscription to a topic; and
- generate a new topic encryption key for the topic.

25. The multicast host of claim 24 wherein the memory contains computer executable instructions stored therein, which when executed by a computer of the multicast host, further directs the multicast host to:

generate a new topic decryption key corresponding to the new topic encryption key.

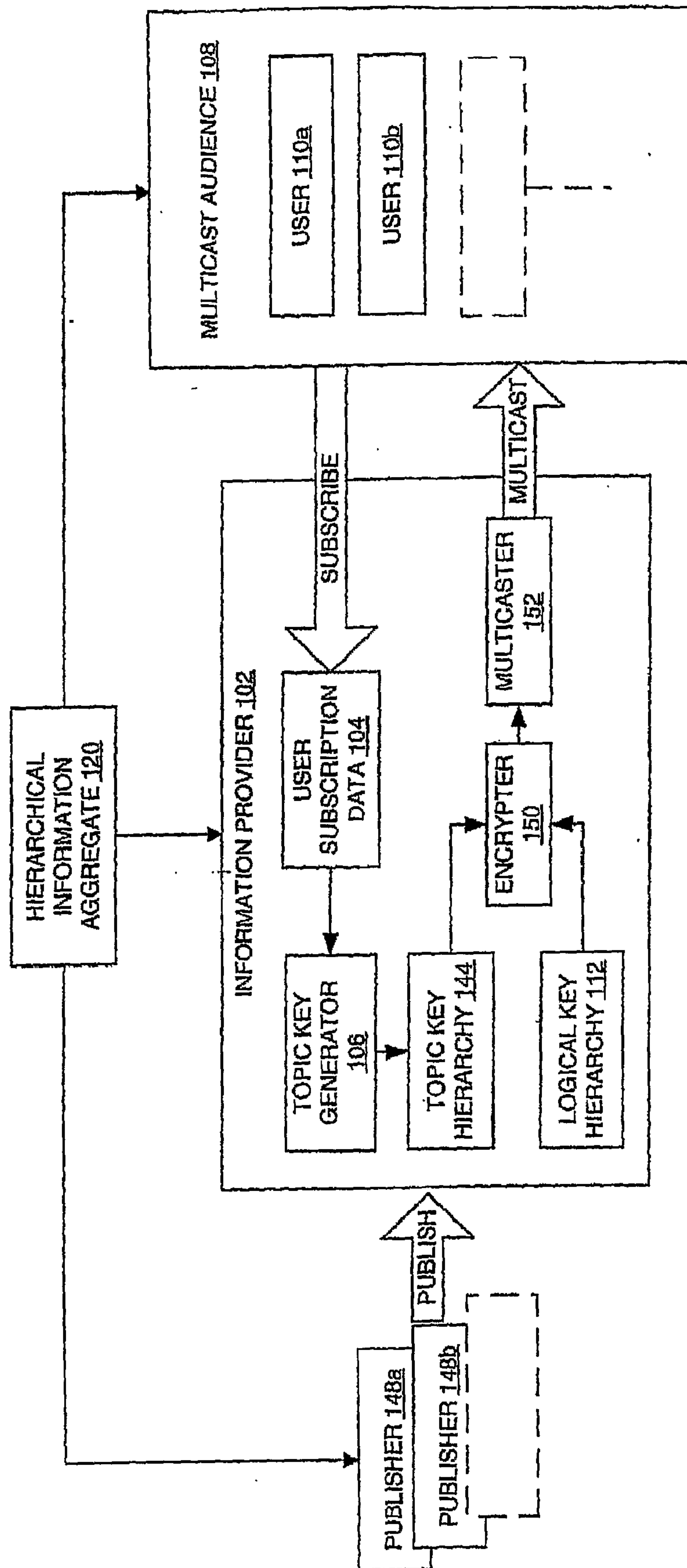
FIGURE 1a

FIGURE 1b

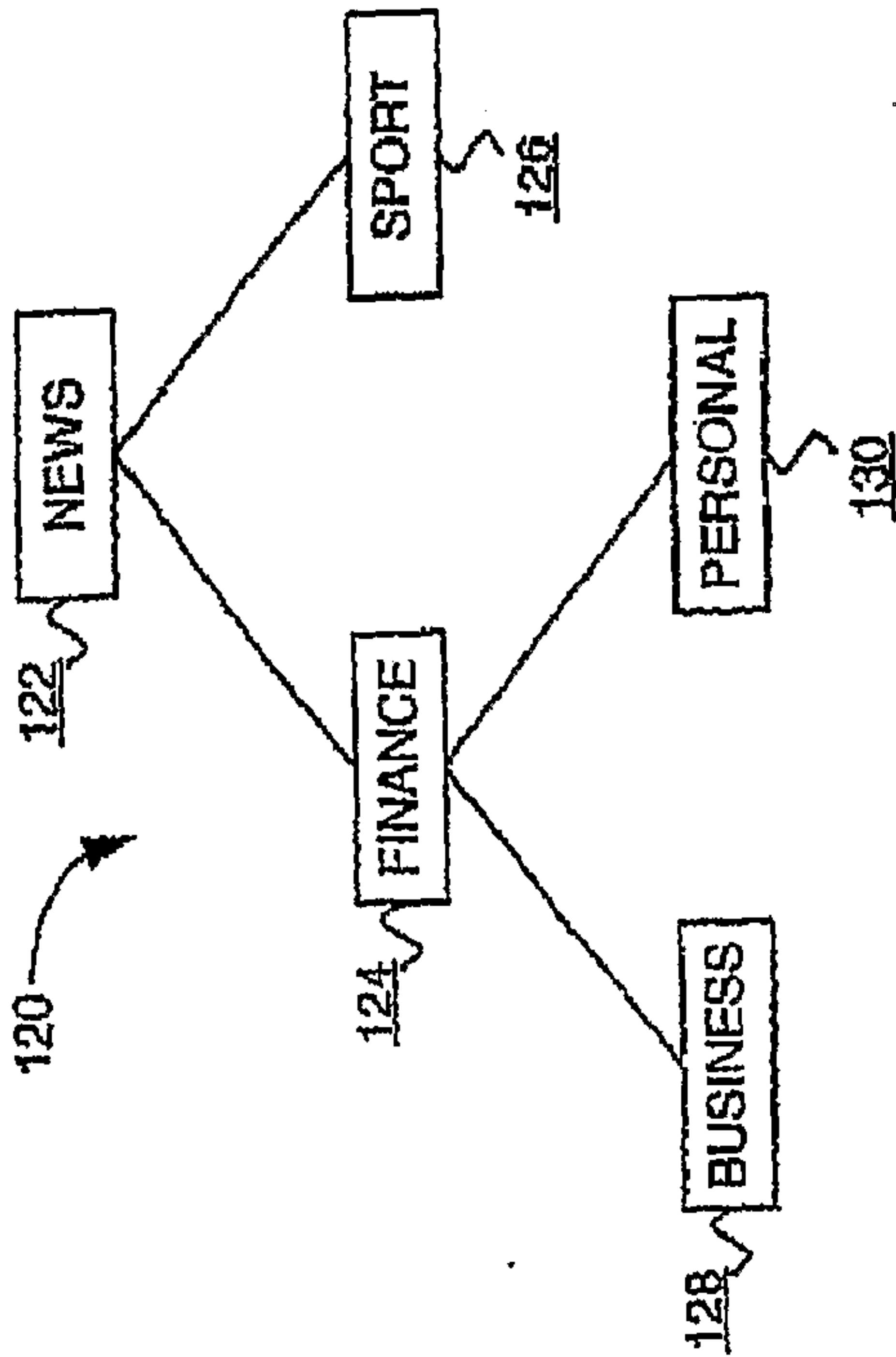


FIGURE 1c

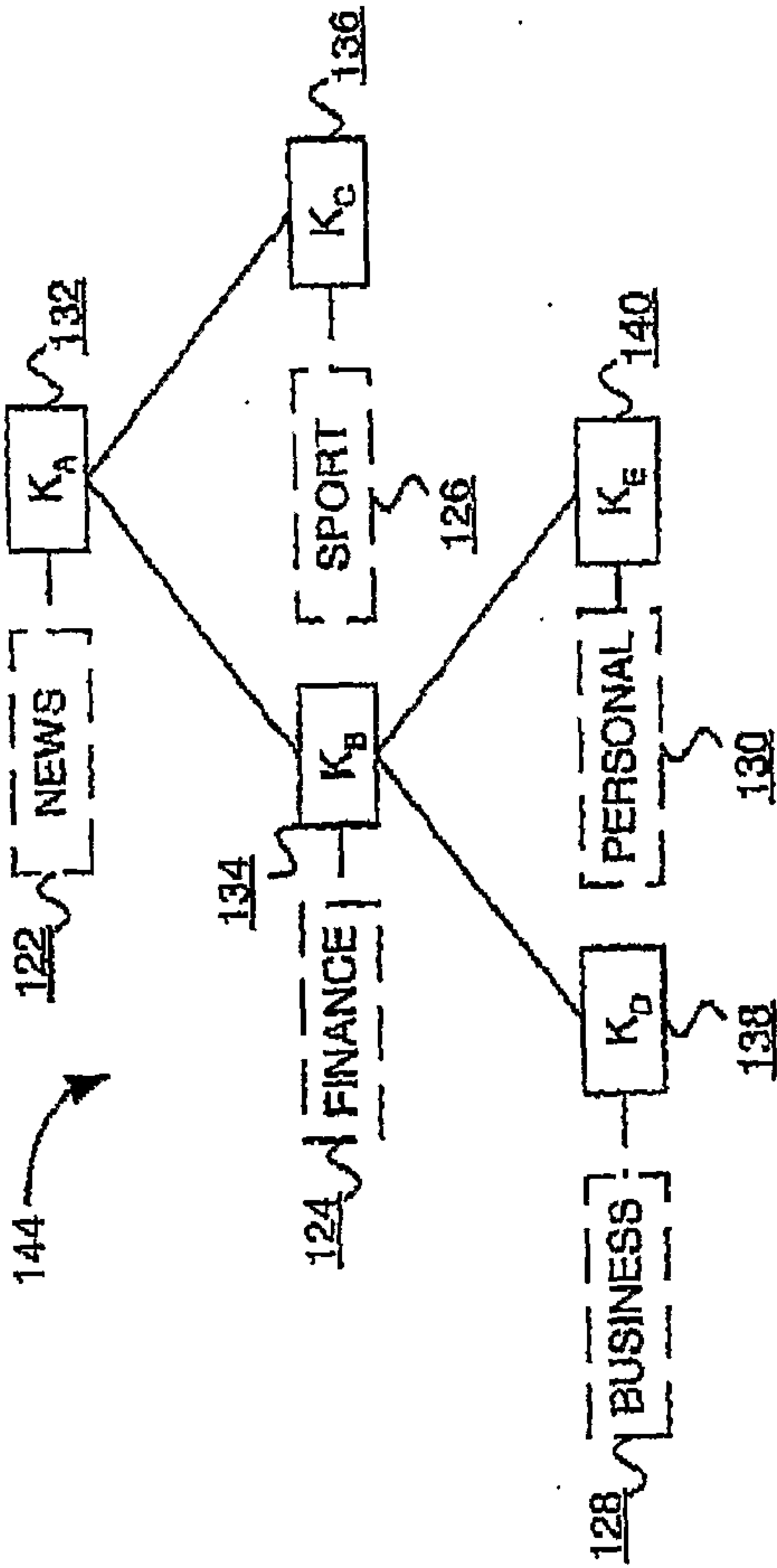


FIGURE 1e

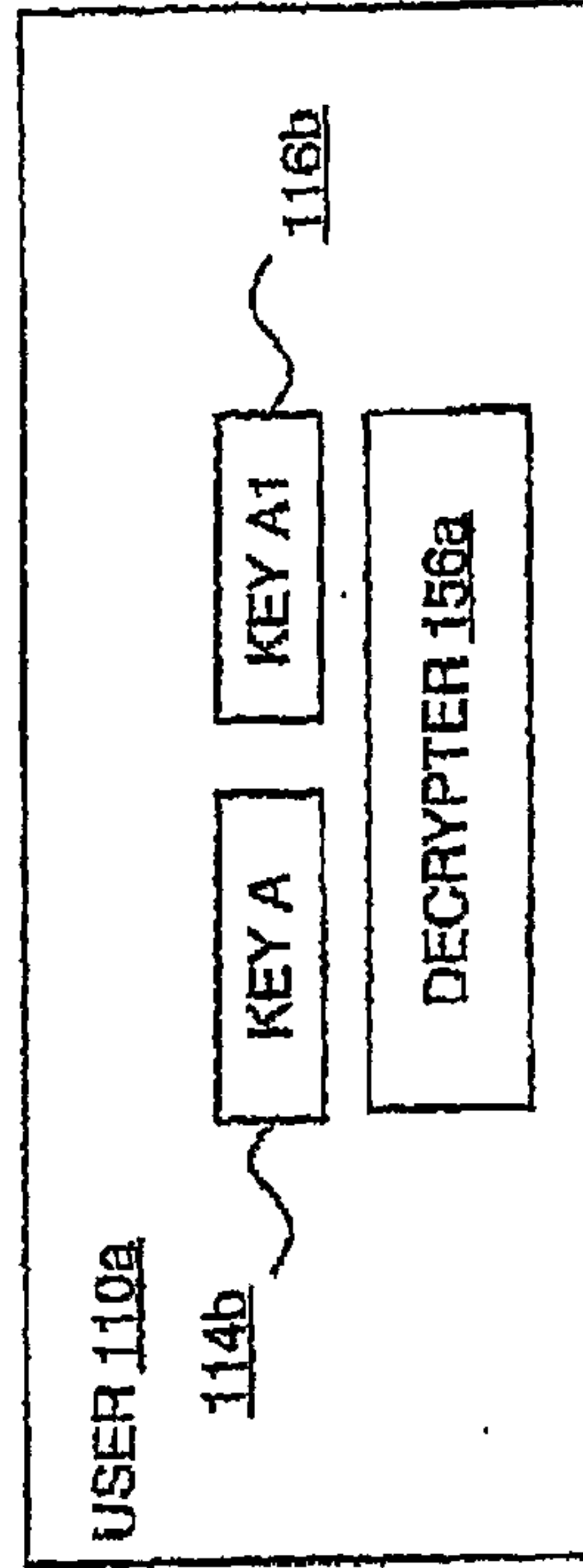
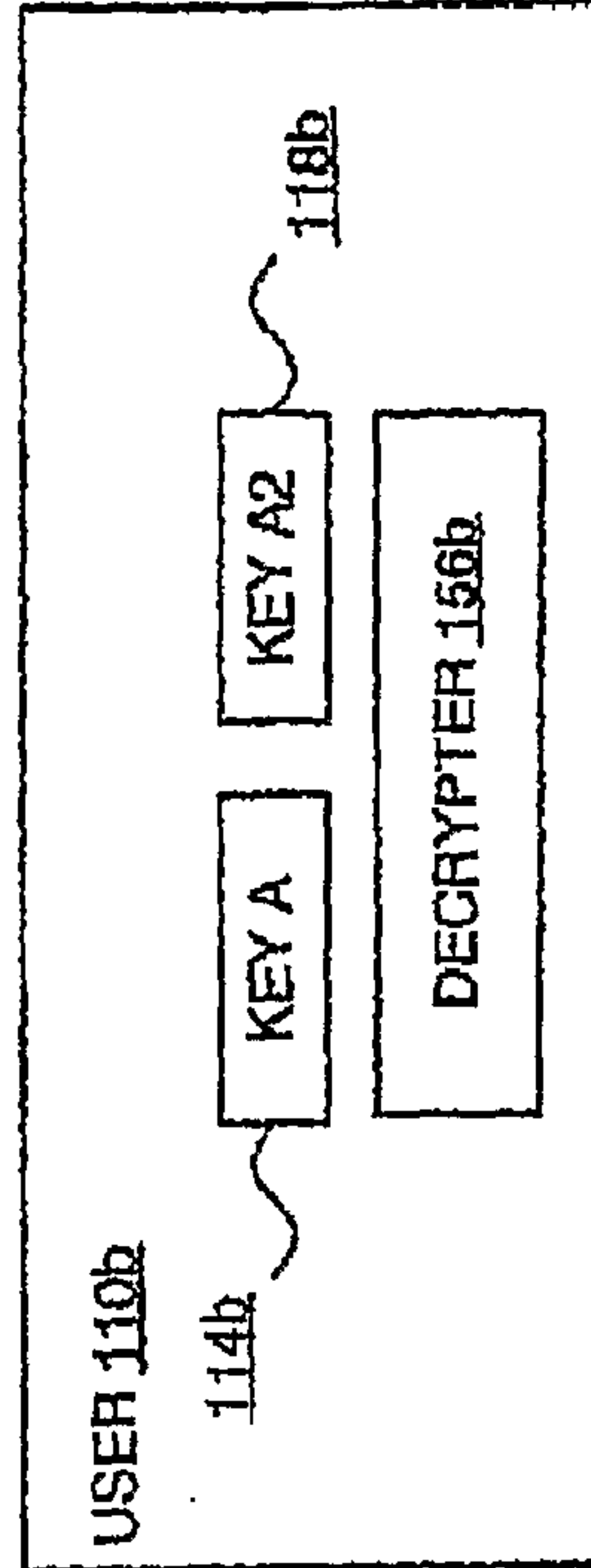


FIGURE 1f



**FIGURE 1d
PRIOR ART**

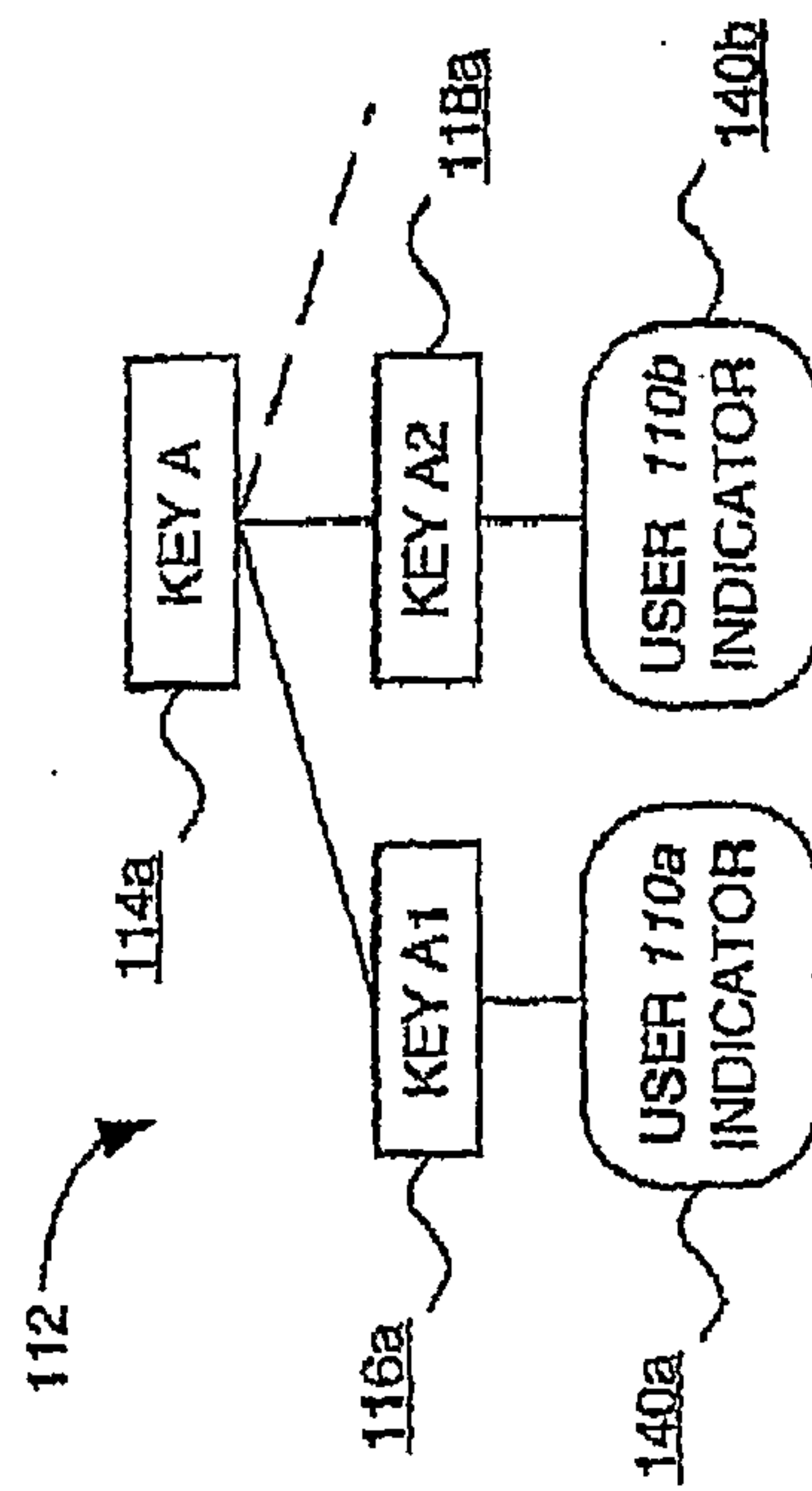
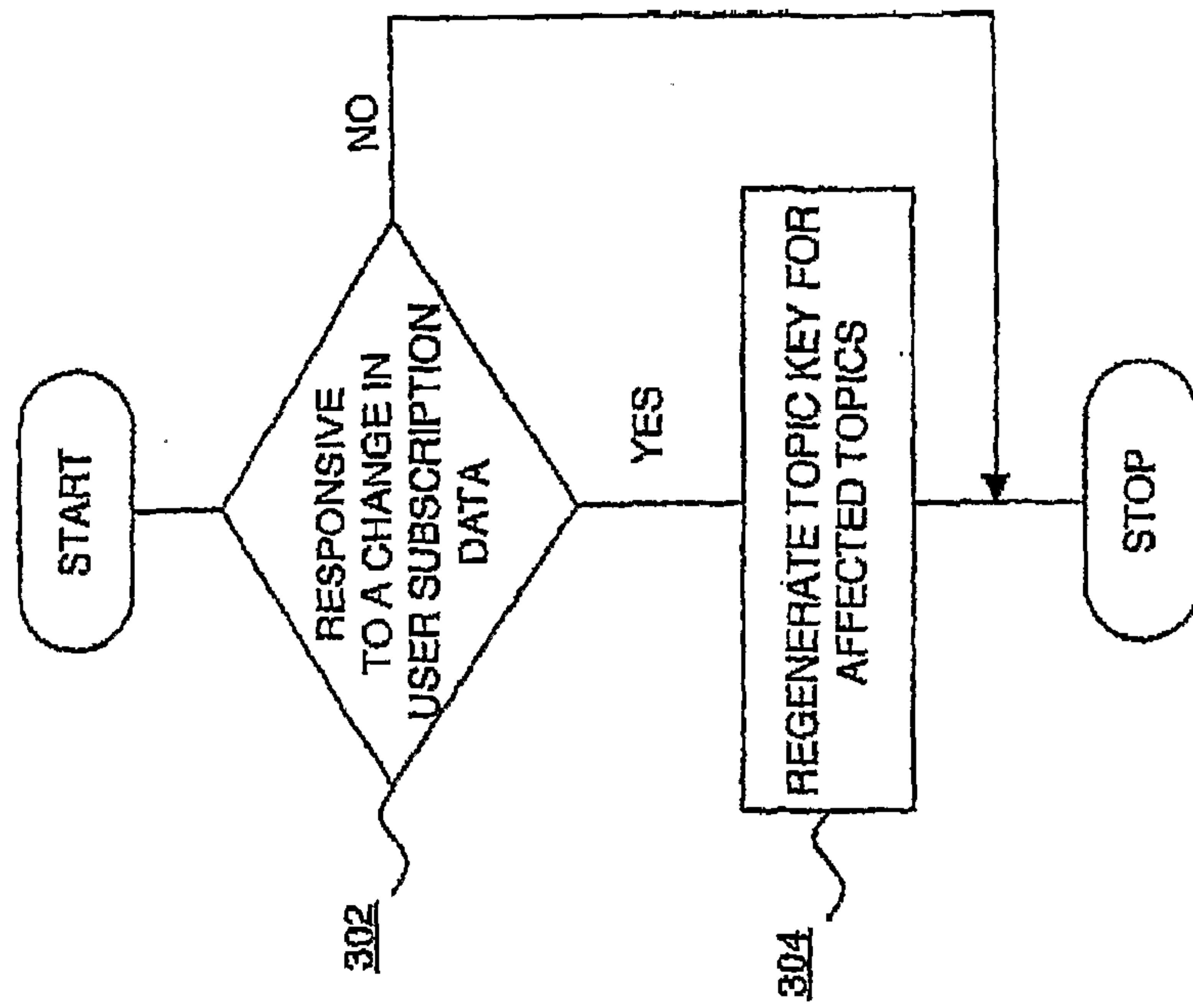
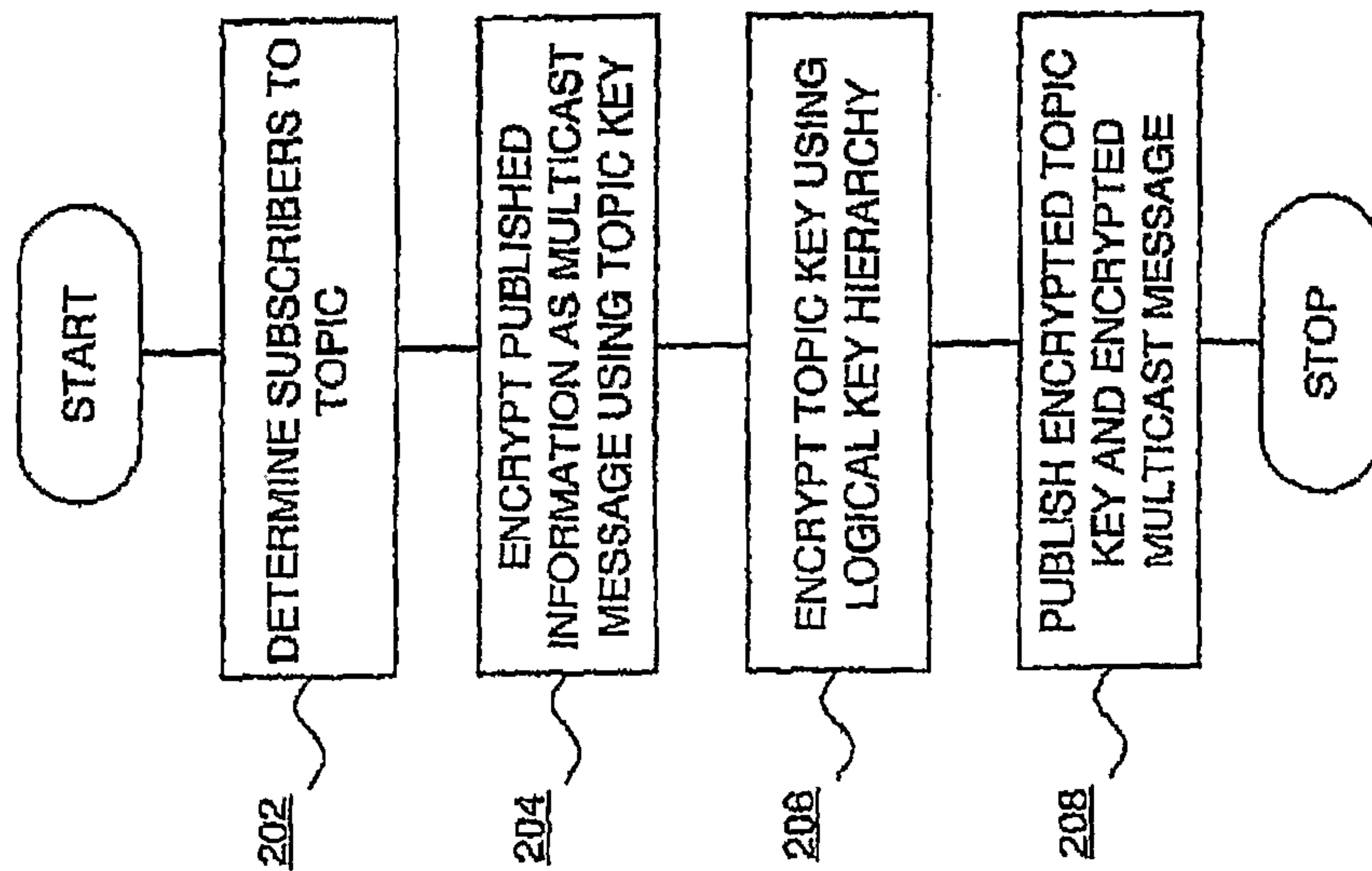


FIGURE 3**FIGURE 2**

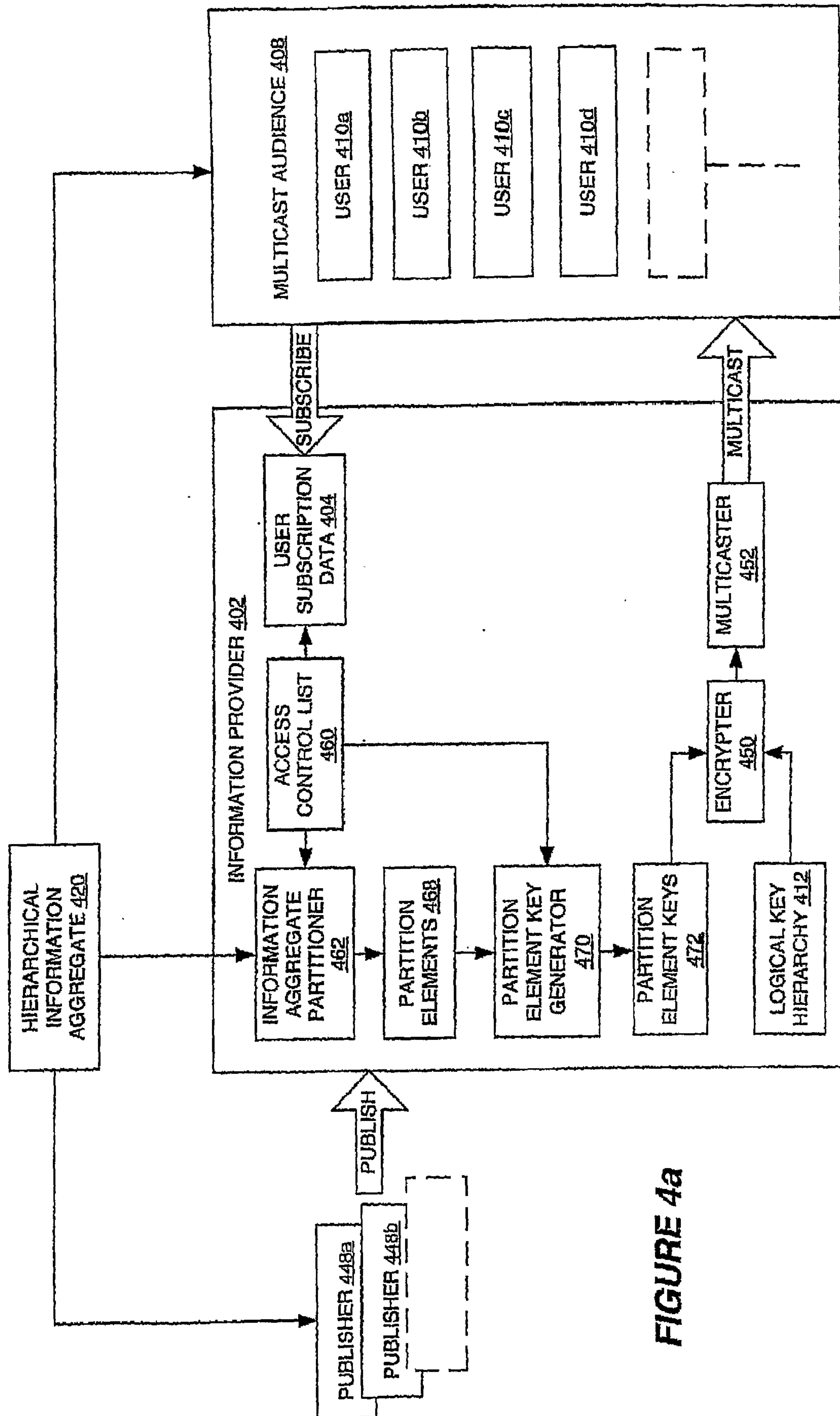


FIGURE 4a

FIGURE 5a

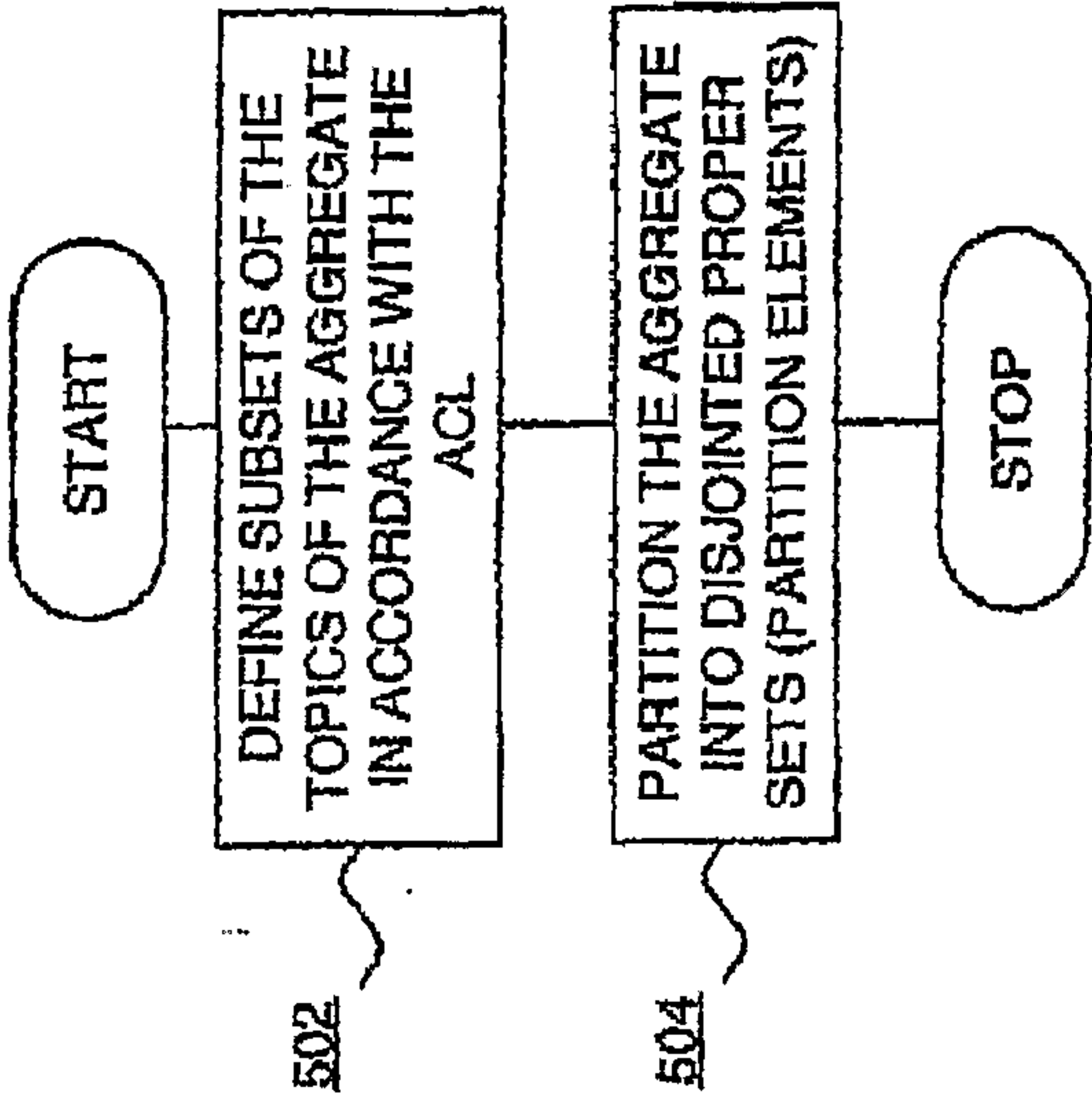


FIGURE 4b

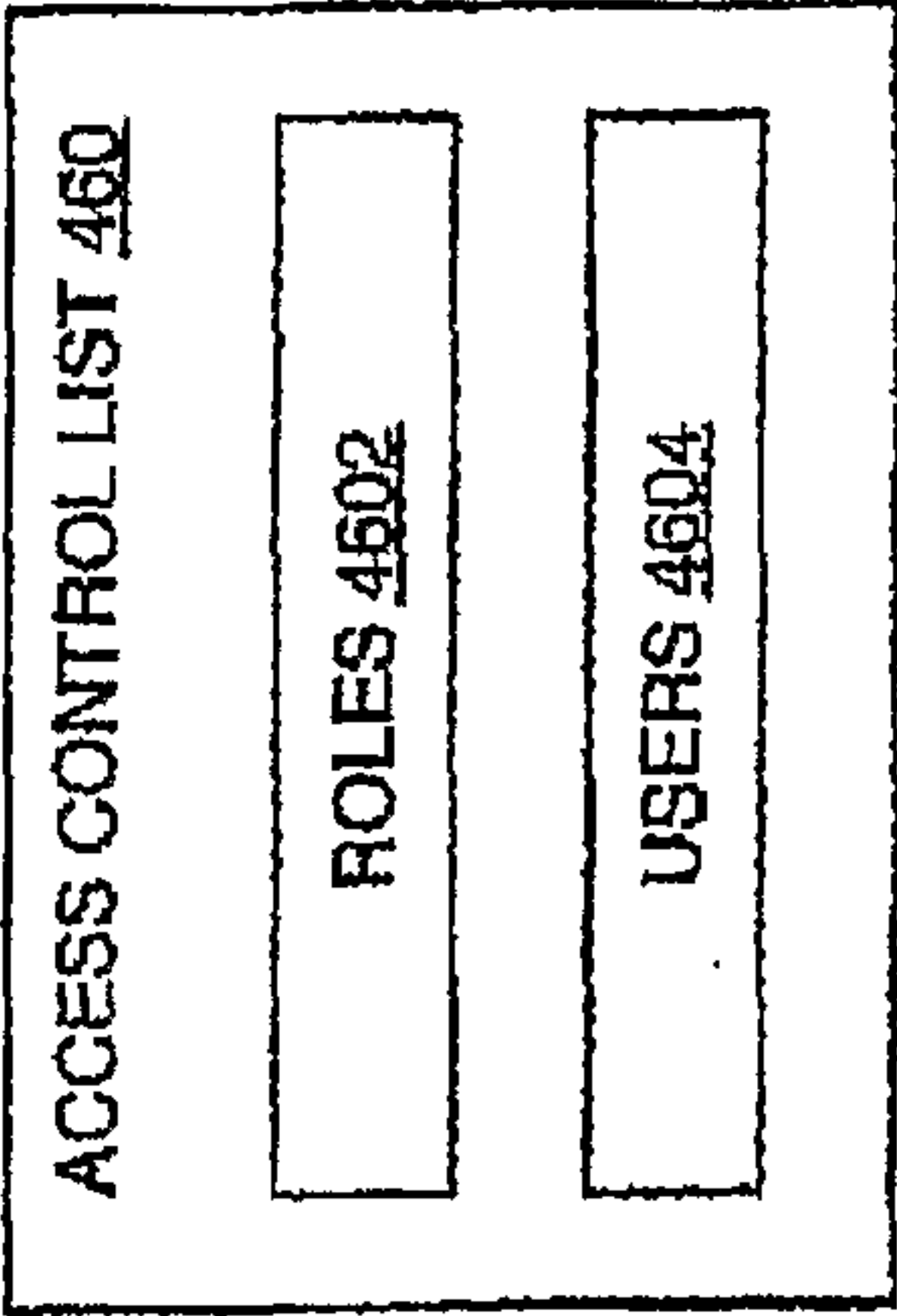


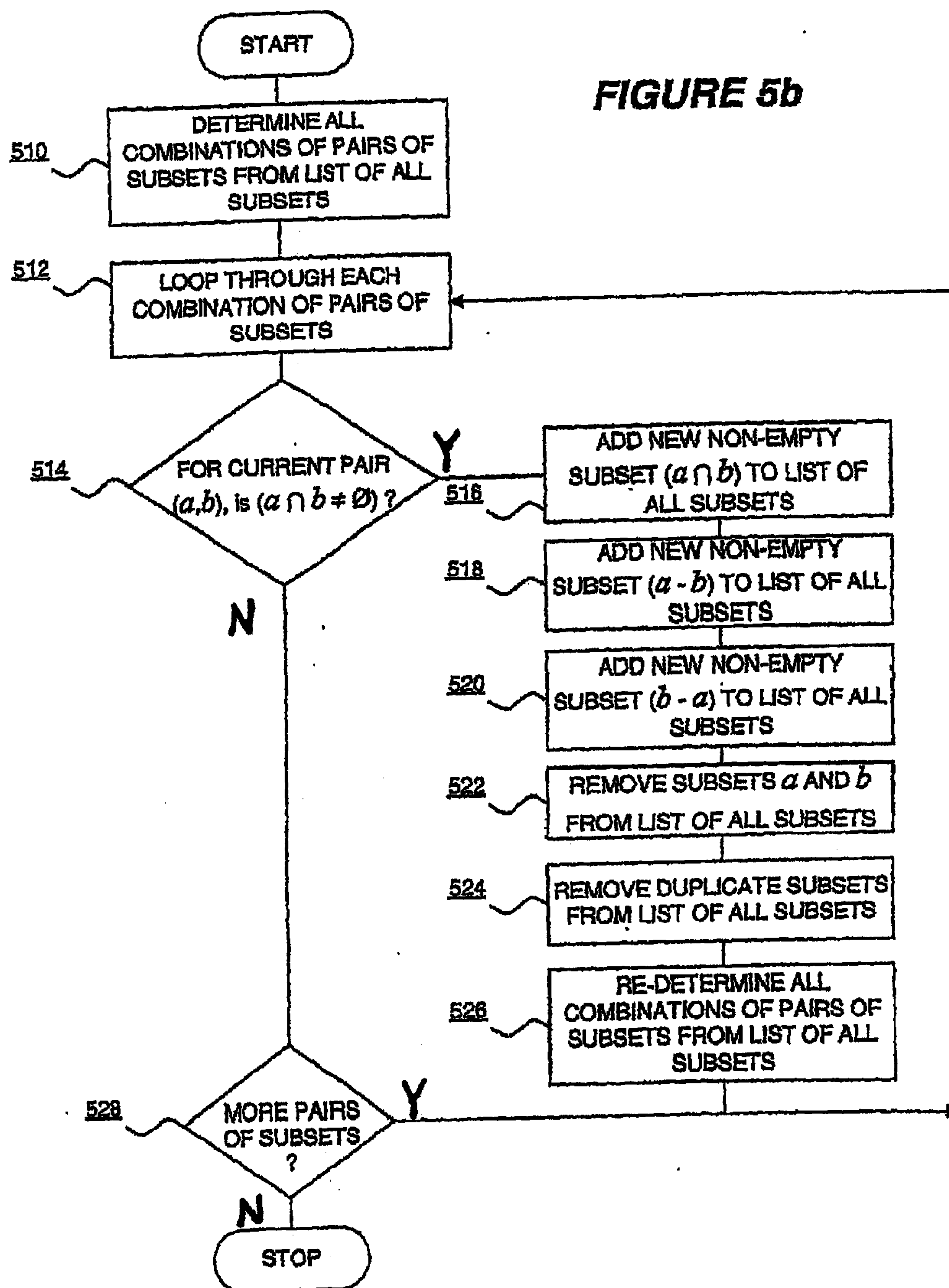
FIGURE 5b

FIGURE 5c

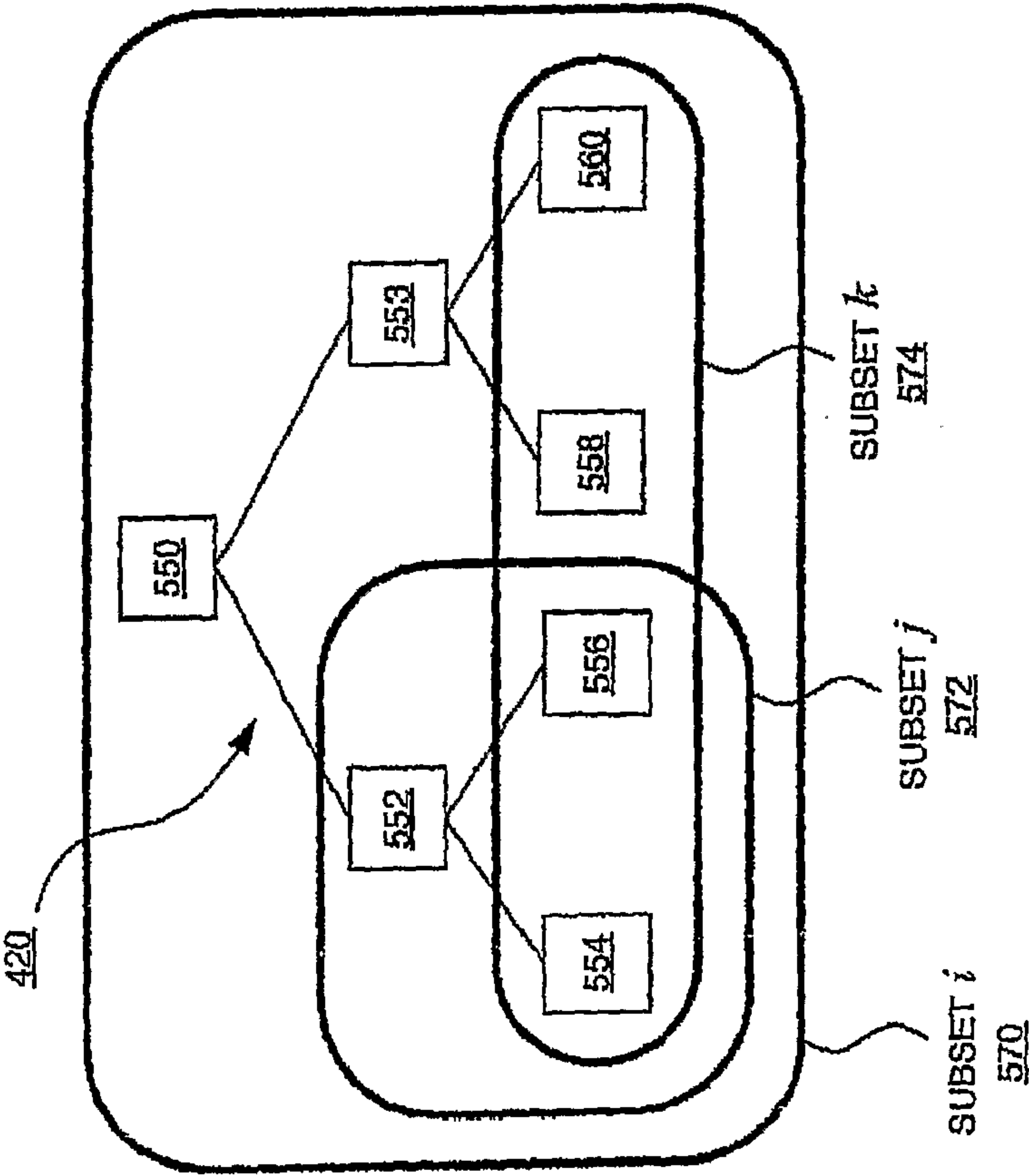


FIGURE 5d

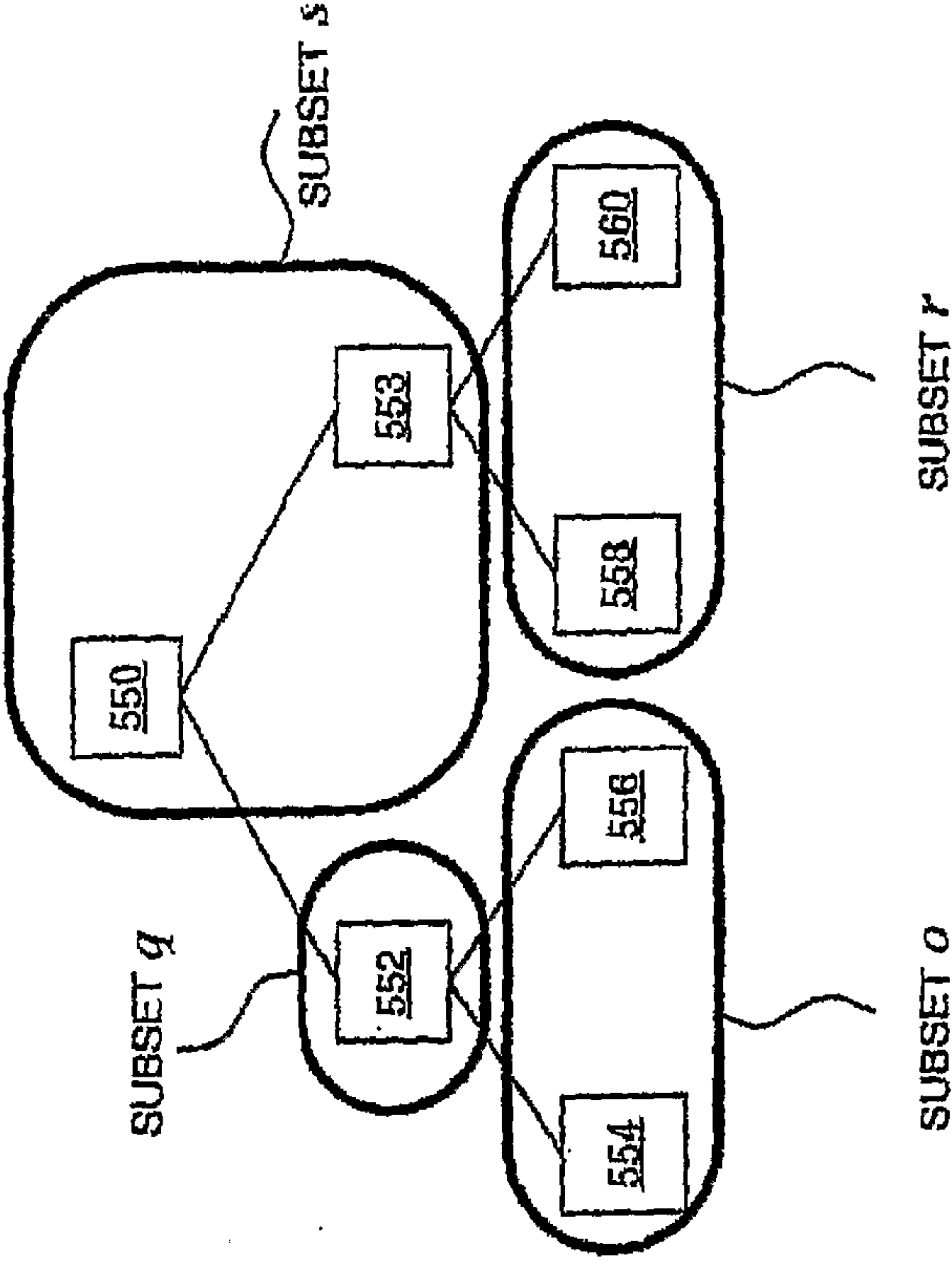


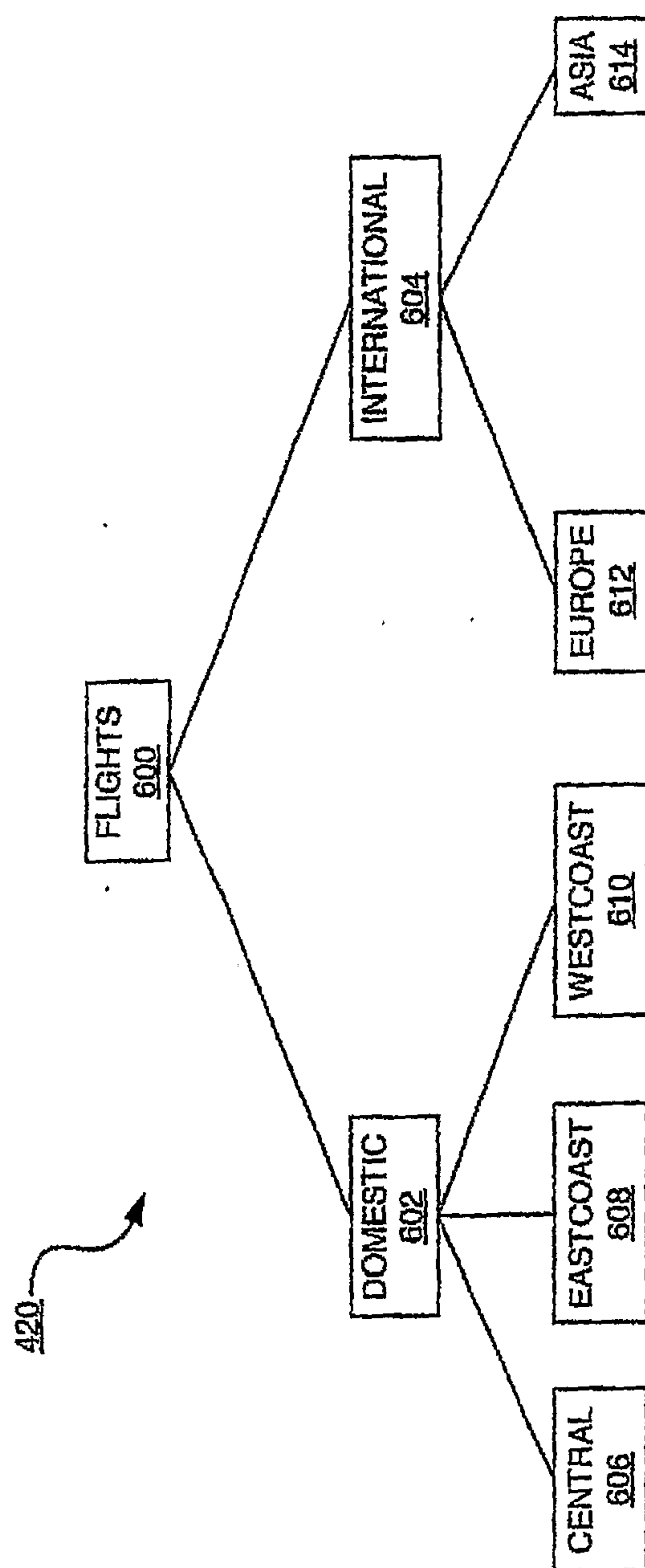
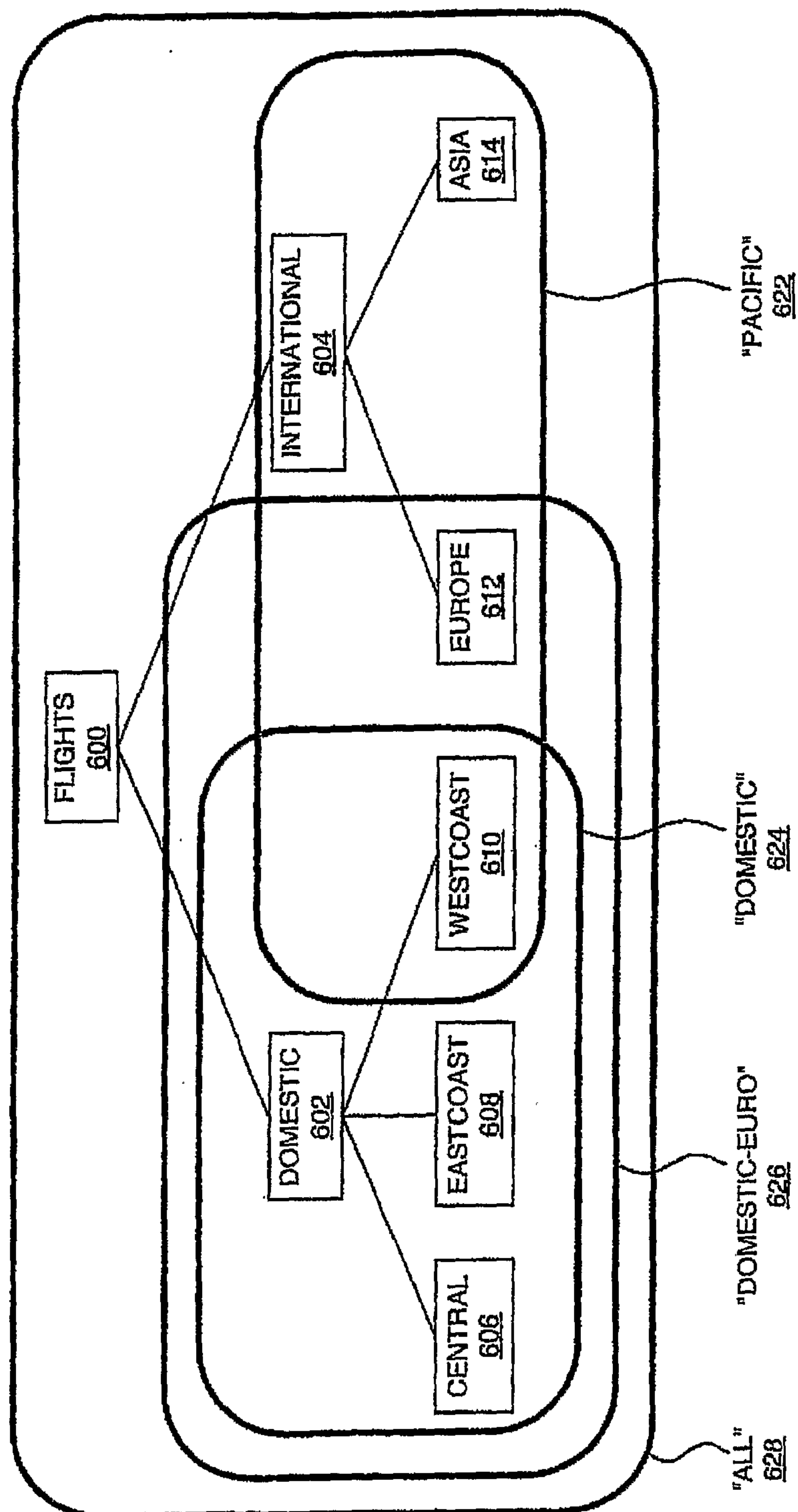
FIGURE 6a

FIGURE 6b

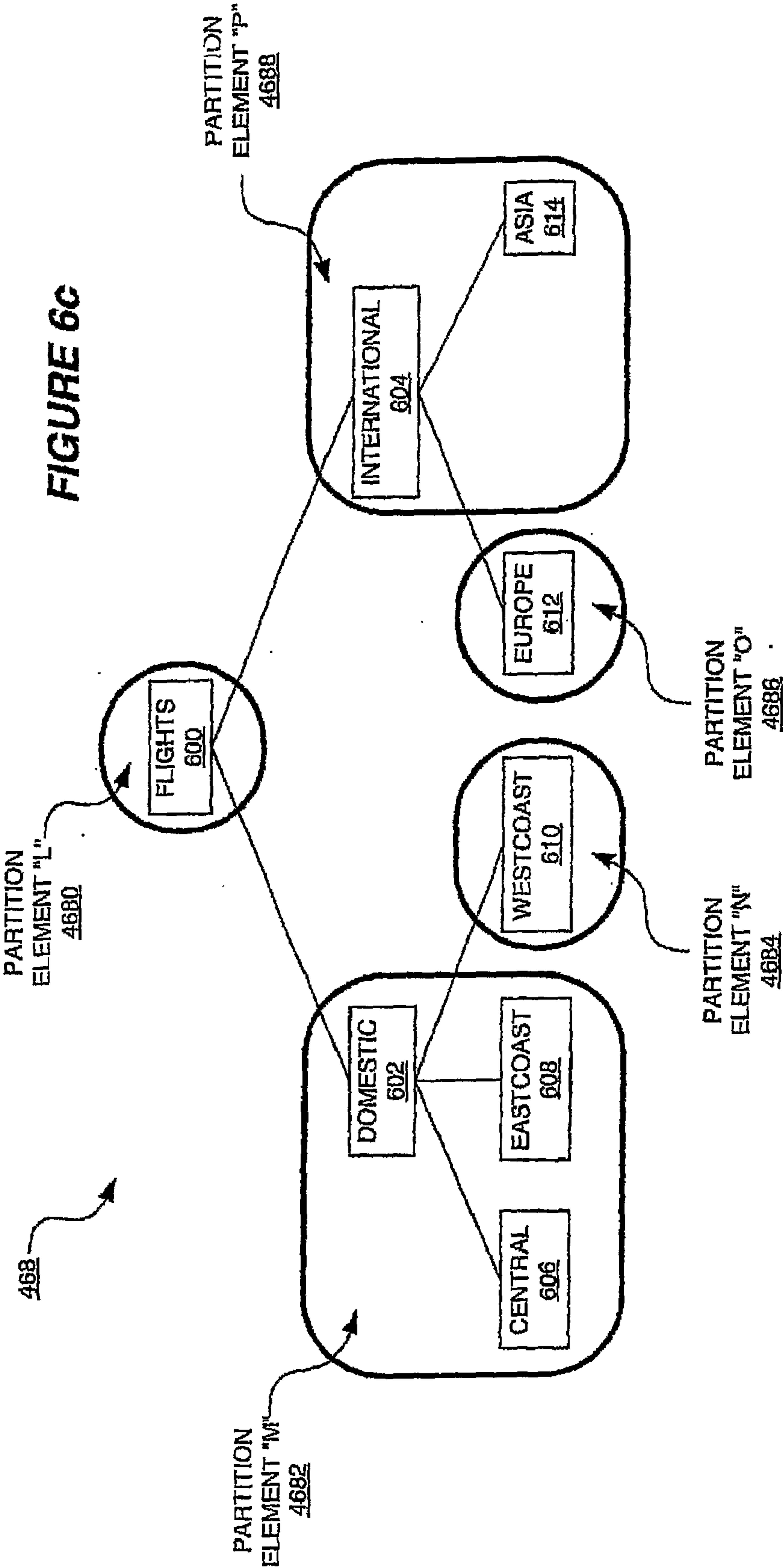


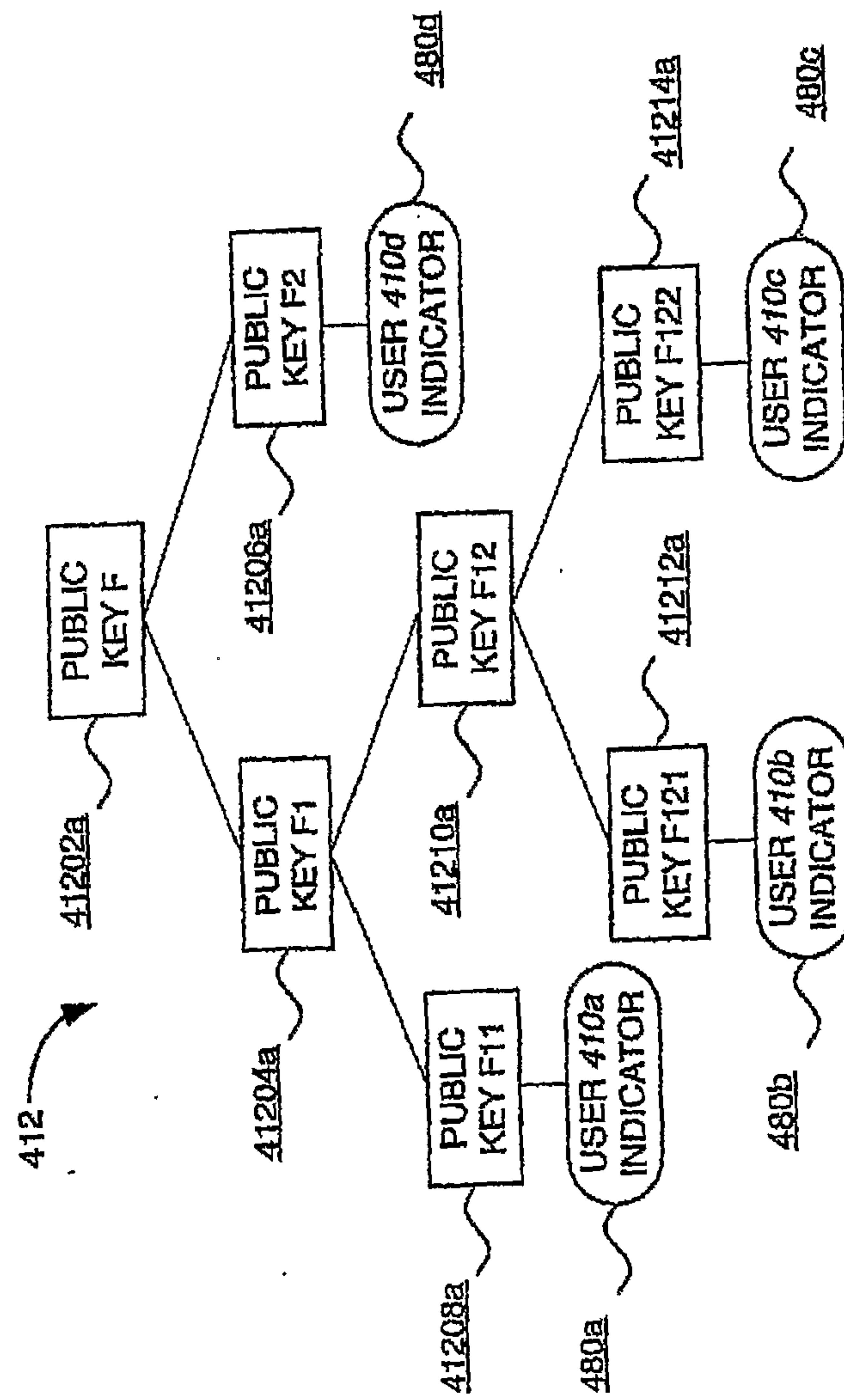
FIGURE 7a

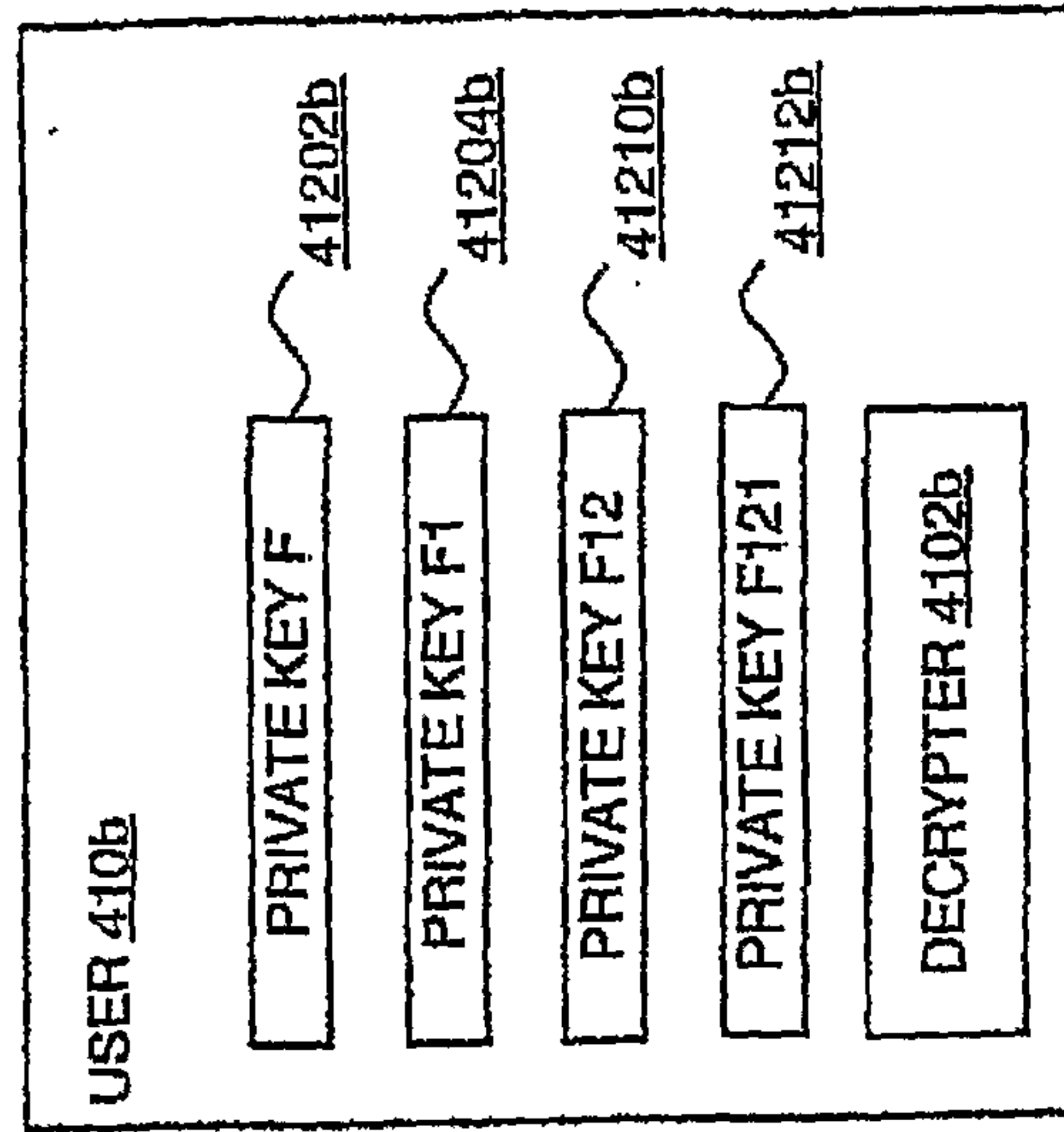
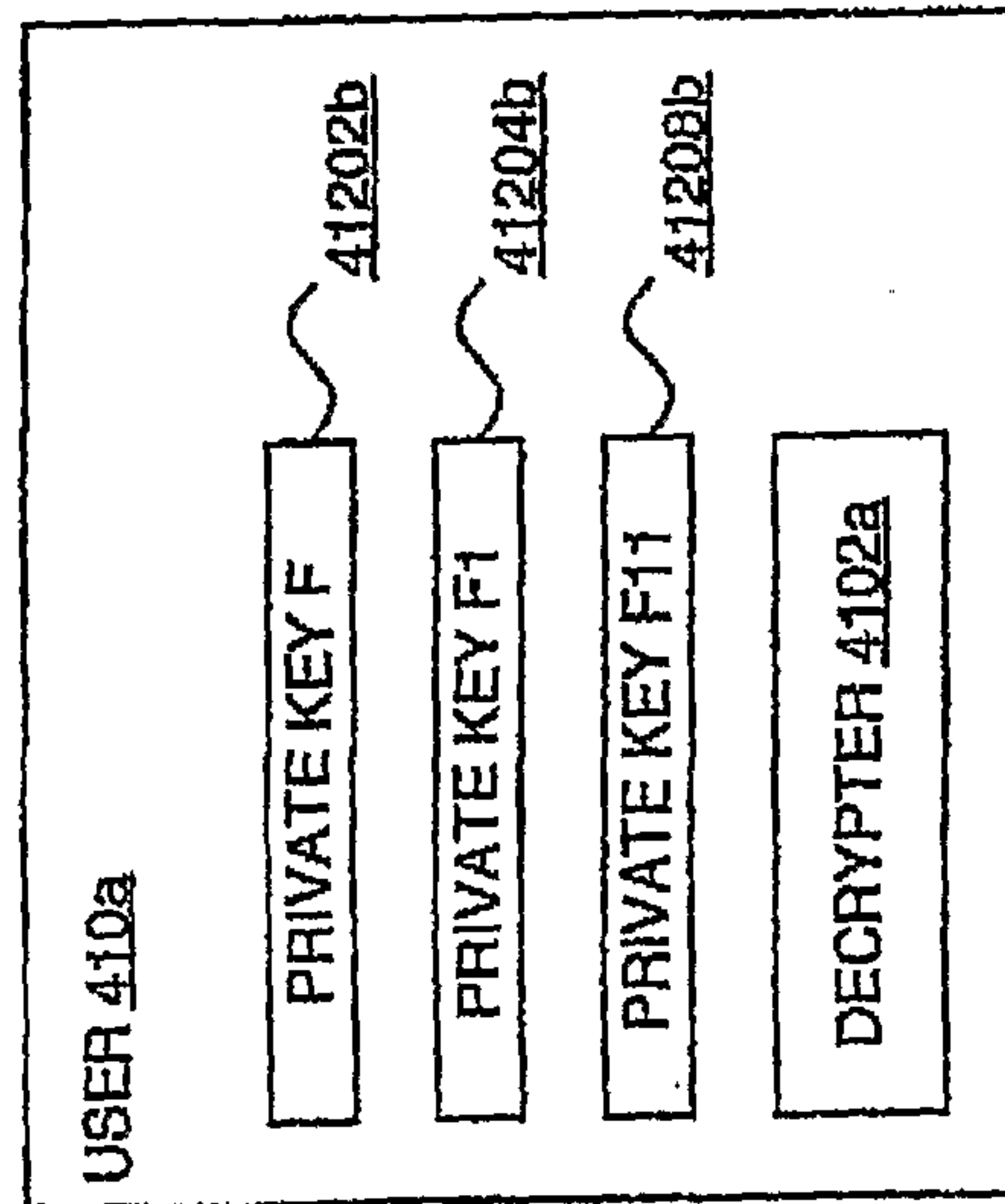
FIGURE 7c**FIGURE 7b**

FIGURE 7d

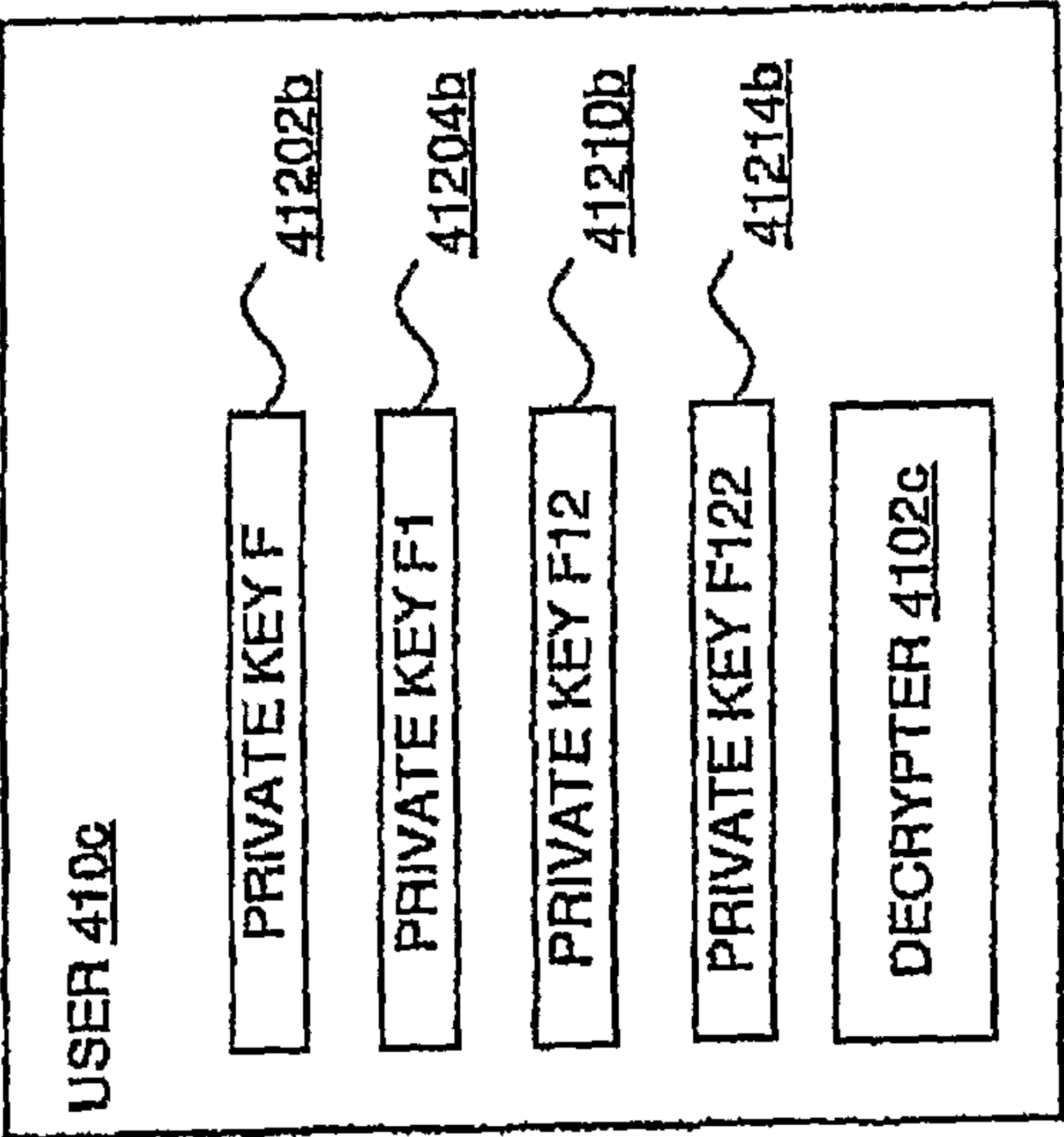


FIGURE 7e

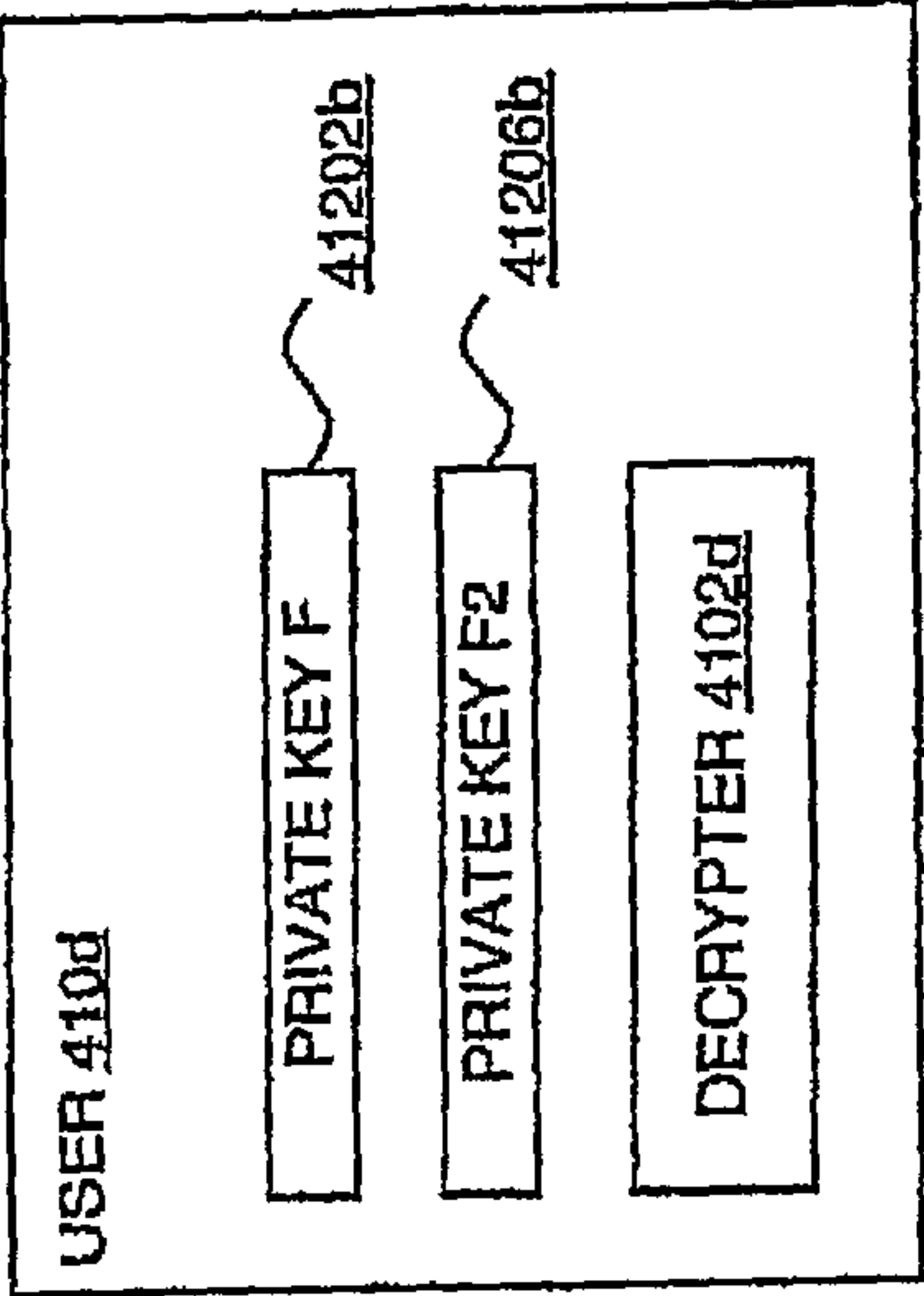


FIGURE 8