PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
G06F 1/00

A1

(11) International Publication Number: WO 00/68762

(43) International Publication Date: 16 November 2000 (16.11.00)

(21) International Application Number: PCT/US00/12052

(22) International Filing Date: 2 May 2000 (02.05.00)

(30) Priority Data:
09/309,045 10 May 1999 (10.05.99) US

(71) Applicant: SUN MICROSYSTEMS, INC. [US/US]; M/S PALI-521, 901 San Antonio Road, Palo Alto, CA 94303 (US).

(72) Inventors: ELLEY, Yassir, K.; 375A Harvard Street, #27A, Cambridge, MA 02138 (US). ANDERSON, Anne, H.; 28 Minuteman Road, Acton, MA 01720 (US). HANNA, Stephen, R.; 3 Beverly Road, Bedford, MA 01730 (US). MULLAN, Sean, J.; 66 Katherine Road, Watertown, MA 02472 (US). PEARLMAN, Radia, J.; 10 Huckleberry Lane, Acton, MA 01720 (US).

(74) Agents: CHOI, Yong, S.; Cesari and McKenna, LLP, 30 Rowes Wharf, Boston, MA 02110 (US) et al.

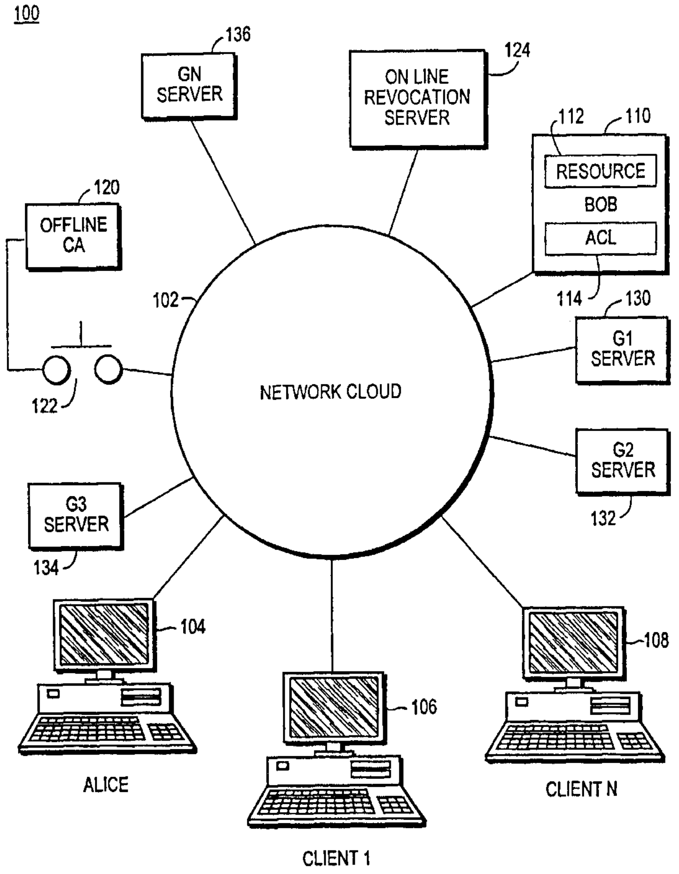
(81) Designated States: AE, AL, AU, BA, BB, BG, BR, CA, CN, CR, CU, CZ, DM, EE, GD, GE, HR, HU, ID, IL, IN, IS, JP, KP, KR, LC, LK, LR, LT, LV, MA, MG, MK, MN, MX, NO, NZ, PL, RO, SG, SI, SK, TR, TT, UA, UZ, VN, YU, ZA, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND SYSTEM FOR DYNAMIC ISSUANCE OF GROUP CERTIFICATES

(57) Abstract

In accordance with the invention, on-line group servers issue group membership or group non-membership certificates upon request. Furthermore, when a requester requests a group certificate for a particular entity, the associated group server makes a dynamic decision regarding the entity's membership in the group rather than simply referring to a membership list. These capabilities provide for, among other things, the implementation of "nested" groups, wherein an entity may indirectly prove membership in a first, or nested, group by proving membership in a second group which is a member of the first group. In the nested group situation, the dynamic decision may involve the group server of the nested group obtaining proof of the entity's membership or non-membership in the second group. Proof of membership or non-membership may include a group certificate and/or a group membership list. Alternatively, the requester may present proof of the entity's membership or non-membership in the second group to the group server of the nested group. In the common case, the requester and the entity will be the same.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania
AM	Armenia
AT	Austria
AU	Australia
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CU	Cuba
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GH	Ghana
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgyzstan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakstan
LC	Saint Lucia
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LS	Lesotho
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
MK	The former Yugoslav Republic of Macedonia
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam
YU	Yugoslavia
ZW	Zimbabwe

METHOD AND SYSTEM FOR DYNAMIC ISSUANCE OF GROUP CERTIFICATES

RELATED CASES

This application discloses subject matter also disclosed in the following co-pending applications, filed herewith and assigned to Sun Microsystems, Inc., the assignee of this invention:

U.S. Patent Application entitled "METHOD AND SYSTEM FOR PRESENTATION OF NON-REVOCATION CERTIFICATES", which application was assigned serial number 09/307,953, filed May 10, 1999; and

U.S. Patent Application entitled "METHOD AND SYSTEM FOR PROVING MEMBERSHIP IN A NESTED GROUP USING CHAINS OF CREDENTIALS", which application was assigned serial number 09/310,165, filed May 10, 1999.

FIELD OF THE INVENTION

This invention relates generally to authorization for a client to access a service in a computer network, and more particularly to the use of group membership and non-membership certificates.

BACKGROUND OF THE INVENTION

During ordinary operation of computer networks it is usual for a client to access a server and to request access to a resource provided by that server. A client may be thought of as a program running on a work station, desktop type computer, personal digital assistant (PDA) or even an embedded device, and a server may be thought of as a program performing a service for a plurality of clients. The client may also be thought of as the computer running the client software, and the server may also be thought of as the computer running the server software. For some purposes, the client may be thought of as a user on whose behalf a request is being made. In some cases, the same computer may run both the client software and the server software. The service is ordinarily provided by the execution of a server program at the request of the client. Specifically, the service provides a resource to the client. The resource may be any operation that is executed, affected or controlled by a computer, such as a word processing or spread-sheet program, the transfer of files, or some other data processing function. The resource access may also include the ability to read or to modify entries in a data base, execute or modify a program maintained by the server, or even modify data maintained by another computer in the system.

In deciding whether or not to grant access to a resource, a resource server must answer two questions:

A. "Is the client correctly identifying himself?" and

B. "Is the identified client authorized to access the requested resource?"

The first question involves a process called "client authentication." The second involves reference to an authorization decision mechanism, such as an Access Control List (ACL) maintained by the server and containing a list of individual clients and/or client groups who are permitted access to the resource. The present invention relates to the determination of group membership or group non-membership of resource-requesting clients.

Client authentication can be accomplished using public key cryptographic methods, as described in *Network Security, Private Communication in a Public World*, Charlie Kaufman, Radia J. Perlman, and Mike Speciner, PTR Prentice Hall, Englewood Cliffs, New Jersey, 1995, (Kaufman et al.) at chapters 5, and 7 and 8, pages 129-161 and 177-222. Specifically, client Alice can authenticate herself to resource server Bob if she knows her private key and Bob knows Alice's public key. Bob has obtained Alice's public key in an identity certificate from a trusted certification authority or from a certification authority in a chain extending from a trusted authority. Other methods of authentication may be used and the present invention does not depend on which method is used.

An identity certificate may be revoked. One common method of dealing with revocation involves the use of Certificate Revocation Lists (CRLs) which are analogous to the books of revoked credit card numbers that were at one time published and distributed periodically to merchants. Like these books, CRLs suffer from being expensive to distribute and are therefore infrequently distributed. There may also be a significant period of time between certificate revocation and CRL distribution during which the resource server is unaware of the revocation.

For maximum security, the certificate authority may be off-line and therefore inaccessible on a transaction-by-transaction basis. Moreover, issuance of an identity certificate may be a relatively lengthy process so that, even if the certificate authority is on-line, it is impractical to issue an up-to-date certificate for each transaction. An alternative approach to certificate revocation involves the use of on-line revocation servers which maintain lists of revoked identity certificates. With on-line revocation servers, up-to-date revocation status can be determined.

At the same time, if a revocation server's private key has been compromised, the damage will be more limited than if an on-line certification authority's private key were compromised. Specifically, if the certification authority's private key were compromised, the authority might issue new certificates to unauthorized clients. On the other hand, a compromised revocation server would result only in continued access by a client with revoked authorization. A compromised revocation server can never grant unauthorized access to a client who has never had authorized access. Although a compromised revocation server may wrongly revoke an authorized client, the revocation would only be a denial-of-service attack.

The use of on-line revocation servers, which is analogous to the method employed today for the authorization of credit card purchases, is also expensive because the resource server usually contacts an on-line revocation server at each transaction to determine whether the certificate has been revoked. The OCSP (On-line Certificate Status Protocol) Internet draft of the PKIX working group, draft-ietf-pkix-ocsp-07.txt (posted September, 1998, at <http://www.normos.org/ietf/draft/draft-ietf-pkix-ocsp-07.txt>), specifies that the revocation status for each certificate can be retrieved from the revocation server and cached by the resource server verifying that certificate. Although caching improves resource server efficiency, it still places a burden on the resource server which may already be burdened with the processing of resource access requests.

An authentication and authorization arrangement introduced by the Open Software Foundation (OSF) and known as the Distributed Computing Environment (DCE) model has a central database on a machine known as a "privilege server" or "central trusted authority." When a client logs on to the system the privilege server issues a secret, or symmetric, key certificate (as opposed to a public, or asymmetric, key certificate) identifying all the groups of which the client is a member. The client presents this certificate to any server on which the client wishes to access a resource. The resource server has an ACL for the resource, and the ACL includes both authorized clients and client groups. If neither the client nor any one of the groups of which the client is a member is listed in the ACL, client access is denied. This approach saves some work for the server, but requires that a central trusted authority know all the groups of which the client is a member and also that the client's group list is small enough so that presentation of the entire collection is not unwieldy. The DCE model is described in Kaufman et al. at Section 17.7, pages 455-459.

Another approach to authentication and authorization is provided by the Windows NT operating system, a product of the Microsoft Corporation of Redmond, Washington. NT has the concept of "domains" where a local group is known only within that domain, although clients from other domains can be members of a local group. NT also has "global" groups whose members must be individuals (not groups) from one domain. A global group of one domain can be listed as a member of a local group in any other domain having a trust relationship to the first domain. Much like DCE, this approach also uses a central trusted authority.

The existing network approaches are inflexible in that they use a central trusted authority and/or provide for the issuance of group certificates only on certain occasions, such as when a client joins a group or logs onto the system. Furthermore, a group server will not issue a group certificate for a particular client unless that client is explicitly listed on its group membership list. These limitations hamper the implementation of a “nested” group, wherein a group has other groups, i.e., subgroups, as members and client membership in the nested group may be indirectly proven through client membership in a subgroup. Nested groups are difficult to implement on existing systems because, among other things, the membership lists of each of these groups may be stored on different machines on the network. Therefore, what is needed is a more flexible approach to the issuance of group certificates.

SUMMARY OF THE INVENTION

In accordance with the invention, on-line group servers issue group membership or group non-membership certificates upon request. Furthermore, when a requester requests a group certificate for a particular entity, the associated group server makes a dynamic decision, regarding the entity's membership in the group, which may be more involved than simply referring to a membership list. These capabilities provide for, among other things, the implementation of "nested" groups, wherein an entity may indirectly prove membership in a first, or nested, group by proving membership in a second group which is a member of the first group. In the nested group situation, the dynamic decision may involve the group server of the nested group obtaining proof of the entity's membership or non-membership in the second group. Proof of membership or non-membership may include a group certificate and/or a group membership list. Alternatively, the requester may present proof of the entity's membership or non-membership in the second group to the group server of the nested group. In the common case, the requester and the entity will be the same.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further advantages of the invention may be better understood by referring to the following description in conjunction with the accompanying drawings in which like reference numbers indicate identical or functionally similar elements:

Fig. 1 is a block diagram of a computer network;

Fig. 2 is an example of an Access Control List (ACL);

Fig. 3 is an example of a non-revocation certificate;

Fig. 4 is a flow diagram of a client access authorization procedure;

Fig. 5 is a second example of an ACL;

Fig. 6 is a flow diagram of a group membership access authorization procedure; and

Fig. 7 is an example of a group family tree.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Introduction

The basic concept of the invention is to support the dynamic issuance of group certificates through the use of on-line group servers which issue group membership or group non-membership certificates upon request to a requester. The exemplary embodiment is directed to the client-server situation wherein the client is not individually authorized for access to a resource but may gain access by means of a group membership certificate (necessary for access to a particular resource) or a group non-membership certificate (when a group is specifically excluded from access to a resource). These certificates will include time stamps designating the date and time of issue. For each resource that it protects, a resource server typically establishes an expiration period beyond which an issued certificate ceases to be valid.

Each group has a name and the location of its group server can thus be obtained from a system directory. The group also has a public key and an associated private key which is used for signing group certificates. Further, a group can have as members individuals and other groups. That is, a "parent", or "nested", group may have "child" groups for members. It may even have a complicated Boolean expression for membership, such as G1 → (G2 AND G3) AND NOT (G4), meaning that all members of groups G2 and G3 are in the group G1, except for members of group G4.

A group membership or group non-membership certificate usually indicates membership status for a specified name, e.g., client "Alice" is a member of group G1, although the certificate may also indicate membership status for a specified public key or other identity. In most cases, there will be a group membership list associated with a group which will be maintained by an on-line group server. However, the on-line group server may need to dynamically decide whether a given client is a member of the group, i.e. the server may do more than simply refer to a membership list. In this case, group membership will be determined by some other criterion. For example, group membership may be determined by a particular attribute of a client. In another case, where the client may be a member of a child group, the on-line group server may obtain proof of the client's membership in the child group. Alternatively, the client may present the proof of membership in the child group to the on-line group server.

A new group membership certificate can be obtained from an on-line group server at any time and presentation of the certificate to the resource server will be sufficient to prove membership in the group. However, an off-line group server infrequently issues certificates, such as when a client joins the group or when the entire membership list is updated. As a result, the client will request a newly-issued non-revocation certificate from an associated on-line revocation server and present it, along with the group membership certificate, to the resource server.

Group Memberships and Nested Groups

As discussed above, a group may have as its members other groups, or subgroups and the client may contact child group servers to obtain proof of membership in a child group. For example, the aforementioned client Alice may be attempting to access a resource on resource server "Bob". If Alice is not listed as an individual on the resource ACL, but groups G1, G2 and G3 are listed on the ACL, Bob returns to Alice the message:

"Access denied, unless you can prove membership in group G1, G2 or G3."

In contrast to traditional systems, this message does not have to be sent during session establishment (i.e., the initial handshake between the client and the server). It may be the case that Alice had previously established the session with Bob and at this later time has decided to access the resource protected by Bob. At this point Bob may challenge Alice to present additional credentials. Alice may have recently obtained a membership certificate for one of these "root" groups in the course of obtaining access to some other server or for some other reason. If not, the client system can prompt the human operator to provide guidance as to the groups of which the client is likely to be a member. This may save substantial time if there are a large number of groups on the ACL.

If human intervention is not desirable, an exhaustive search may be undertaken: Alice communicates with on-line group servers containing the group membership lists of groups G1, G2 and G3 and attempts to obtain a membership certificate from one of these servers.

In another variation, rather than performing an exhaustive search, Alice may be able to narrow the search by relying on previously stored information to determine groups in which Alice is likely to be a member. For example, if Alice has an old group membership certificate for group G1, Alice can attempt to obtain a new group membership certificate from the G1 group server before undertaking an exhaustive search for a group certificate.

Although Alice may not be listed as a member of group G1, group G1 may be a nested group, i.e., it may be a parent to the child groups, or subgroups, G5 and G6. The G1 server will ask Alice:

"Can you prove membership in group G5 or G6?"

Alice then communicates with the G5 and G6 servers. For example, if group G5 lists Alice as a member, the G5 server returns a group membership certificate in group G5. Alice returns to the G1 server to request a group membership certificate, armed with the certificate from the G5 server. The G1 server then grants Alice a group membership certificate. Now, armed with the certificate from root group G1, Alice can go to Bob and obtain access to the requested resource. A group membership certificate is not the only mechanism by which Alice may prove membership in group G5 to the G1 server. For example, Alice may alternatively present the group G5 membership list, signed by group G5, or some other proof of group membership.

The example presented above is rather simple. In some cases, Alice will be unable to establish membership in either a root or a child group and will be denied access to the resource. In other cases, Alice may have to search down several subgroup levels before finding membership in a group. To facilitate this task, Alice maintains a family tree for each root group, tracing the path of subgroups visited during a search. Alice can easily detect and abort loops (where G5 is a member of G1 is a member of G5 is a member of G1 and so on). When membership in a subgroup is found, Alice moves back up the path collecting a group membership certificate from each successive group server and presenting it to the next higher group server until the root group is reached. Alice then presents to Bob the group membership certificate issued by the root group server.

In the above scenario, it has been assumed that the group servers issuing group membership certificates are on-line and thus create newly-issued group certificates at runtime. In that case, the group membership certificates created at runtime are fresh enough so as not to need any further proof of non-revocation. If a group certificate is "old", i.e., it was obtained by the client more than some specified time prior to a request for access to a resource, as ascertained from a time stamp included in the certificate, the resource server will require a newly-issued certificate from the on-line group server.

In another variation, rather than asking Alice to present proof of membership in group G5 or G6, the G1 server may decide to do the work. In this case, the G1 server will directly communicate with the G5 and/or G6 server(s) to determine whether Alice is a member of one of these groups.

In a different example, the G1 group server may grant membership to anyone who can prove membership in group G11 and non-membership in group G12. Accordingly, Alice will retrieve a group membership certificate from the G11 group server and a group non-membership certificate from the G12 group server and present those certificates to the G1 group server. The G1 group server will then issue a G1 group membership certificate which Alice will present to Bob.

Group Non-membership Certificates

A resource server may also prohibit access to a resource based on client membership in one or more groups. In this case, the client will gather and present group non-membership certificates stating that the client is not a member of the designated groups. For example, group G1 members may be permitted access to a resource, unless they are also group G2 members. Alice will have to prove both membership in group G1 and NON-membership in group G2. To prove non-membership in group G2, Alice will present a group G2 non-membership certificate to Bob. Alice requests a non-membership certificate from the G2 group server and presents the certificate, along with a group G1 membership certificate to Bob.

The work required to gather the credentials necessary to prove group non-membership is more intensive than that required for group membership. For each prohibited root group, the client will be required to prove non-membership in each and every group extending from the root. For example, Bob may deny resource access to all members of group G2. Therefore, Alice will request a group non-membership certificate from the G2 server. The root group G2 might have as members the child groups, or subgroups, G7 and G8. The G2 group server will ask Alice:

"Can you prove non-membership in groups G7 and G8?"

Alice then requests a group non-membership certificate from both the G7 and G8 servers. If group G7 also lists the groups G9 and G10, Alice requests a group non-membership certificate from both the G9 and G10 servers. Alice presents the G9 and G10 group non-membership certificates to the G7 server which then issues a group non-membership certificate. Alice next presents the G7 and G8 group non-membership certificates to the G2 server and receives a G2 group non-membership certificate. Now, armed with a group non-membership certificate from group G2, Alice can go to Bob and prove non-membership in root group G2.

An Embodiment of the Invention

As shown in Fig. 1, a computer network 100 includes a network "cloud" 102 that provides the interconnection for devices on the network. The network cloud 102 may represent a simple local area network, for example, an Ethernet on one floor of a building. At the other extreme, it may represent the entire worldwide Internet. The network cloud 102 may contain transmission lines, repeaters, routers, network backbones, network interconnect points, etc., depending upon the extent of the network which it represents.

A client can be any device capable of sending messages over the network and is generally thought of as an individual workstation, a desk-top computer, a mini-computer accessed by a terminal, a personal digital assistant (PDA), an embedded device, or some other relatively simple computer. A client is often a computer operated by one person, although an independently operating computer or a program operating without human intervention can also be a client. Client computer Alice 104 and two additional client computers 106, 108 are shown connected to the network cloud 102. A modern network may include thousands of client computers.

A resource server Bob 110 is also connected to network cloud 102. A resource server can be any device capable of receiving messages over a network and is usually thought of as a larger computer which contains resources to which client computers desire access. For example, a resource may be a data base, a file system, etc. A resource 112 on resource server Bob 110 represents any resource to which a client may desire access. An Access Control List (ACL) 114 contains a list of clients which are permitted to access the resource 112. As a convenience, clients may be assigned membership in groups of clients, designated groups G1, G2, G3, ..., GN, having associated group servers 130, 132, 134, 136. Accordingly, ACL 114 may also contain the names of groups whose member clients are permitted access to the resource 112.

An Off-line Certification Authority (OCA) server 120 issues identity certificates used by clients to identify themselves when seeking access to various resources on various servers, such as client Alice 104 access to resource 112. A switch 122 represents the ability of the OCA server 120 to be temporarily connected to the network cloud 102 so that it may, at selected times, issue an identity certificate to a client. The switch 122 is in "open" position most of the time to protect the OCA server 120 from attacks by malicious persons.

An On-line Revocation (OR) server 124 is connected to network cloud 102 on a substantially permanent basis. The OR server 124, upon request from a client, issues a non-revocation certificate stating that a particular client's identity certificate, previously issued by the OCA server 120, has not been revoked as of the time stamp. The non-revocation certificate is then transmitted to the requesting client.

Fig. 2 shows a typical Access Control List (ACL) 200 having a name field 202, in this case "112", and access entries. The first access entry 204 specifies that client Alice 104 is permitted access. Additional access entries for client computers x1 and x2 205, 206, along with groups G1, G2 and GN 208, 210, 212, round out the list.

Fig. 3 shows a typical non-revocation certificate 300 issued to client Alice 104 by the OR server 124. Client Alice 104 had previously obtained a certificate from the OCA server 120. The OR server 124 maintains a list of certificates which have been revoked. Upon receipt of a request from a client, the OR server 124 checks its revocation list and, assuming that the subject certificate is not on that list, issues a non-revocation certificate. The first entry 302 in the non-revocation certificate 300 indicates that a previously issued certificate for client Alice 104 has not been revoked. Additionally, the non-revocation certificate 300 includes a signature entry 304, and a time stamp comprising an issue date entry 306 and time entry 308.

Resources may have recency requirements for credentials, such as non-revocation certificates, group membership certificates and group non-membership certificates. For example, resource server Bob 110 may require that the credentials used to access the resource 112 be no more than one-day old, or possibly no more than 10 minutes old, depending upon the level of security desired for the resource 112, the number of clients requesting the resource 112, and the number of requests which OR server 124 can handle.

Fig. 4 is an illustrative flow diagram 400 of the client access authorization procedure. Each entity on the computer network includes a processor with an associated memory which may contain instructions for performing one or more steps of the procedure. Persistent storage of these instructions may be in a server system remote from the network entity and its processor. The electrical signals that carry digital data representing the instructions are exemplary forms of carrier waves used for transporting information from a server system to a network entity. At block 402 client Alice 104 "decides" to request access to the resource 112. For example, the decision may be initiated by a human typing the appropriate command, or clicking a cursor on an appropriate icon, etc. In an alternative example, client Alice 104 may have an internal timer or other event that prompts it to make a request for the resource 112.

At decision block 404 client Alice 104 determines whether it has a recently-issued non-revocation certificate issued by a trusted authority, or a set of non-revocation certificates each corresponding to a particular identity certificate. A recently-issued certificate may be stored in the cache, for example, as the result of an earlier request for access to the resource 112.

If client Alice 104 has a recently-issued non-revocation certificate, it transmits an access request over the computer network 100 to resource server Bob 110, along with its identity and non-revocation certificates, at block 406.

At decision block 408 resource server Bob 110 attempts to validate the identity and non-revocation certificates presented at block 406. For each identity certificate, resource server Bob 110 determines whether the corresponding non-revocation certificate is valid. The validity of the non-revocation certificate is determined by verifying its signature and by further verifying that its time stamp falls within the recency requirements for the resource. If the validation fails, access is denied at block 410.

If the validation of the certificates is successful, at decision block 412 resource server Bob 110 attempts to authenticate client Alice 104. As described above, a variety of authentication methods may be employed by resource server Bob 110. If the authentication fails, access is denied at block 410.

If the authentication of client Alice 104 is successful, at decision block 414 resource server Bob 110 determines whether client Alice 104 is listed on the resource ACL 200. If client Alice 104 is listed, access is granted at block 416. Otherwise, the procedure branches to decision block 602 of the flow diagram 600 of FIG. 6.

If at decision block 404, client Alice 104 does not have a recently-issued non-revocation certificate, client Alice 104 requests a new non-revocation certificate from the OR server 124 at block 418. In response, the OR server 124 checks its list of revoked identity certificates, and if client Alice 104 does not appear on the list of revoked certificates, the OR server 124 issues a non-revocation certificate. Client Alice 104 may store a copy of the non-revocation certificate in its cache for use whenever it desires access to a resource.

Client Alice 104 is allowed a specified number of attempts (e.g. 5) to obtain a non-revocation certificate from OR server 124 before the process aborts. It is desirable to permit such attempts because network congestion, server congestion, or similar problems may cause inadvertent failures. If the specified number of attempts is exceeded at decision block 420, then no further attempts are allowed and the access authorization procedure terminates at block 422. Human intervention may reset the revocation list in OR server 124. In an exemplary embodiment of the invention, the OR server 124 will simply not respond in the event that the identity certificate for client Alice 104 has been revoked. Accordingly, decision block 420 is necessary to shut down requests from client Alice 104. In an alternative embodiment of the invention, a message stating that the identity certificate has been revoked is returned to client Alice 104 from the OR server 124. This message can be added to decision block 420 to bring the procedure to a halt before the number of attempts is exceeded.

In summary, the computer network 100, the ACL 200 of the resource 112 of resource server Bob 110, the issuance of identity certificates by the OCA server 120, the issuance of non-revocation certificates by the OR server 124, and the exemplary access authorization procedure traced by the flow diagram 400 provide a secure and scaleable security system. The work of gathering non-revocation certificates is handled by the clients, and a resource server is not burdened with checking revocation status for each of the respective clients that request access to resources.

Groups of Computers and Nested Groups

Fig. 5 illustrates an ACL 500 for resource server Bob 110 in which client Alice 104 is not listed individually. Instead, ACL 500 identifies groups G1, G2 and G3 as having authenticated access to the resource 112. Any client which can prove that it is a member of a group having authenticated access to the resource 112 has access individually.

Fig. 6 is an illustrative flow diagram 600 of the group membership access authorization procedure. Again, each entity on the computer network includes a processor with an associated memory which may contain instructions for performing one or more steps of the procedure. If client Alice 104 can prove that it is a member of either a listed group or a sub-group of a listed group, then it is authenticated for access to the resource 112. Decision block 602 is entered by transfer from decision block 414 of the client access authorization procedure shown in Fig. 4. The resource server Bob 110 has determined at block 414 that client Alice 104 is not listed on the ACL for resource 112 and therefore does not have an individual client authorization for access.

If at decision block 602, the ACL 500 did not list any groups with authorization for access to the resource 112, the procedure terminates at block 604. In the present example, however, at block 606 resource server Bob 100 returns a message to client Alice 104 stating that groups G1, G2, and G3 have access to the resource 112.

At block 608 client Alice 104 searches for and locates the address of the G1 server 130 which maintains the membership list for group G1; the address of the G2 server 132 which maintains the membership list for group G2; and, finally, the address of the G3 server 134 which maintains the membership list for group G3.

At block 610 client Alice 104 establishes a family tree for each root group designated by resource server Bob 110 at block 606 as having resource access. Below, at block 632, additional groups may be added to the family tree when a parent identifies one or more child groups, or subgroups. This addition is recursive and subgroups continue to be added to the family tree maintained at block 610 until client Alice 104 proves membership in a group or all subgroups have been identified.

At block 612 one root group is selected for determination of its membership list. The group may be selected by any useful criterion, for example, alphabetical by group name, numerical by address, or by the order in which the groups were added to the list, etc.

At block 614 client Alice 104 transmits to the group server selected in block 612 a request for a membership certificate stating that client Alice 104 is a member of the group. At block 616, client Alice 104 receives a reply to the request sent out at block 614.

If at decision block 618 client Alice 104 does not receive a group membership certificate, it is then determined at decision block 628 whether any other groups are members of the selected group. At block 630 client Alice 104 locates the group servers for any identified subgroups and at block 632 these subgroups are added to the appropriate family tree maintained at block 610.

If at decision block 628 no additional groups are determined to be members of the family tree of the selected root group, and if at decision block 634 all of the root groups maintained at block 610 have been checked, client Alice 104 does not have access through group membership and the procedure terminates at block 604.

If at decision block 634 all root groups maintained at block 610 have not been checked, the next root group is selected at block 612. The new group selected is then investigated in order to determine if client Alice 104 is a member of that group or any subgroup. The procedure continues until all identified root groups and their family trees have been investigated.

If at decision block 618 client Alice 104 receives a group membership certificate, client Alice 104 moves back up the family tree, presenting a certificate of membership in each child group to each higher level parent group server at block 620. At block 622 client Alice 104 transmits to resource server Bob 110 the group membership certificate associated with the highest group in the chain, i.e. the root group authorized for access on the resource ACL 114.

At decision block 624 resource server Bob 110 attempts to validate the group certificate presented at block 622. The validity of the group certificate is determined by verifying its signature and by further verifying that its time stamp falls within the recency requirements for the resource. If the validation fails, access is denied at block 604, otherwise access is granted at block 626.

An exemplary family tree maintained by client Alice 104 is shown in Fig. 7. It has been determined from the procedure that client Alice 104 is an individual member of group G6, as shown at the first entry 702. It has also been determined that group G6 is a member of group G5, as shown at the second entry 704; group G5 is a member of group G4, as shown at the third entry 706; and group G4 is a member of group G1, as shown at the fourth entry 708. As a member of group G6 it can prove membership in group G5. Next, as a member of group G5 it can prove membership in group G4. Finally, as a member of group G4 it can prove membership in group G1.

Boolean Logic

Examples of the use of Boolean logic to control access of various subgroups to access to the resource 112 were given above. The process flow diagram 600 of Fig. 6, and the resulting credentials which client Alice 104 presents to resource server Bob 110, give the resource server Bob 110 the tools to implement a Boolean logic process to limit access to the resource.

For example, resource server Bob 110 may refuse access to the resource 112 if client Alice 104 is a member of some suspect group. By having the group server responsible for the membership list for the suspect group issue a non-membership certificate, resource server Bob 110 can implement Boolean logic to prevent any client unable to present a non-membership certificate from accessing the resource. For example, if all members of group G3 are denied access to the resource and members of groups G1 and G2 are permitted access to the source, then the Boolean expression:

(G1 AND G2) AND NOT (G3)

will be FALSE in the event that resource server Bob 110 does not receive a valid non-membership certificate indicating that client Alice 104 is not a member of group G3. The FALSE result in the Boolean expression will prevent client Alice 104 from gaining access to the requested resource on resource server Bob 110.

The foregoing description has been directed to client access to a server resource. The present invention, however, can be applied to any computer network transmission, such as an e-mail message, where authorization is required. In addition, a typical network device may assume either the client or the resource server role, i.e., it may be a client in one resource access and a server in another resource access. The foregoing description has also been directed to use of an ACL for client authorization decisions. The present invention, however, can employ many other authorization decision mechanisms known in the art.

The foregoing description has also been directed to specific embodiments of this invention. It will be apparent, however, that other variations and modifications may be made to the described embodiments, with the attainment of some or all of their advantages. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.

What is claimed is:

CLAIMS

1. A method of obtaining proof of group membership in a computer system, comprising the steps of:

   A. presenting by a requester to an on-line server associated with a group a request for a certificate certifying that a particular entity is a member of the group;

   B. determining by the server whether the entity is a member of the group; and

   C. issuing by the server a group membership certificate to the requester if the server determines that the entity is a member of the group.

2. A method of obtaining proof of group non-membership in a computer system, comprising the steps of:

   A. presenting by a requester to an on-line server associated with a group a request for a certificate certifying that a particular entity is not a member of the group;

   B. determining by the server whether the entity is not a member of the group; and

   C. issuing by the server a group non-membership certificate to the requester if the server determines that the entity is not a member of the group.

3. A method for determining entity membership in a group, wherein a server associated with the group performs the step of making a dynamic decision on membership in the group of a particular entity.

4. The method of claim 3, wherein the dynamic decision-making step includes obtaining by the server proof of entity membership in a second group.

5. The method of claim 4, wherein the proof of entity membership comprises a group membership certificate.

6. The method of claim 4, wherein the proof of entity membership comprises a group membership list.

7. The method of claim 3, wherein the dynamic decision-making step includes obtaining by the server proof of entity non-membership in a second group.

8. The method of claim 7, wherein the proof of entity non-membership comprises a group non-membership certificate.

9. The method of claim 7, wherein the proof of entity non-membership comprises a group membership list.

10. The method of claim 3, wherein the server performs the step of making a dynamic decision upon a request from a requester, and wherein the requester performs the step of presenting to the server proof of entity membership in a second group.

11. The method of claim 10, wherein the proof of entity membership comprises a group membership certificate.

12. The method of claim 10, wherein the proof of entity membership comprises a group membership list.

13. The method of claim 3, wherein the server performs the step of making a dynamic decision upon a request from a requester, and wherein the requester performs the step of presenting to the server proof of entity non-membership in a second group.

14. The method of claim 13, wherein the proof of entity non-membership comprises a group non-membership certificate.

15. The method of claim 13, wherein the proof of entity non-membership comprises a group membership list.

16. A computer system wherein a group membership certificate is issued by an on-line certification authority upon request.

17. A computer system wherein a group non-membership certificate is issued by an on-line certification authority upon request.

18. A computer system wherein a server associated with a group makes a dynamic decision on membership in the group of a particular entity.

19. The system of claim 18 wherein the server obtains proof of entity membership in a second group.

20. The system of claim 19 wherein the proof of entity membership is a group membership certificate.

21. The system of claim 19 wherein the proof of entity membership is a group membership list.

22. The system of claim 18 wherein the server obtains proof of entity non-membership in a second group.

23. The system of claim 22 wherein the proof of entity non-membership is a group non-membership certificate.

24. The system of claim 22 wherein the proof of entity non-membership is a group membership list.

25. The system of claim 18 wherein the server makes the dynamic decision on a request from a requester, and wherein the requester presents to the server proof of entity membership in a second group.

26. The system of claim 25 wherein the proof of entity membership is a group membership certificate.

27. The system of claim 25 wherein the proof of entity membership is a group membership list.

28. The system of claim 18 wherein the server makes the dynamic decision on a request from a requester, and wherein the requester presents to the server proof of entity non-membership in a second group.

29. The system of claim 28 wherein the proof of entity non-membership is a group non-membership certificate.

30. The system of claim 28 wherein the proof of entity non-membership is a group membership list.

31. A method of operating an on-line server on a computer network, said server associated with a group and performing the steps of:

A. receiving a request from a network device for proof of membership of a client in the group;

B. making a dynamic decision on whether the client is a member of the group; and

C. issuing to the network device, if the server decides that the client is a member of the group, a group membership certificate proving that the client is a member of the group.

32. The method of claim 31 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership certificate.

33. The method of claim 31 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership certificate and authorizing client access to the resource.

34. A method of operating an on-line server on a computer network, said server associated with a group and performing the steps of:

A. receiving a request from a network device for proof of membership of a client in the group;

B. making a dynamic decision on whether the client is a member of the group; and

C. issuing to the network device, if the server decides that the client is a member of the group, a group membership list proving that the client is a member of the group.

35. The method of claim 34 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

36. The method of claim 34 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership list and authorizing client access to the resource.

37. A method of operating an on-line server on a computer network, said server associated with a group and performing the steps of:

A. receiving a request from a network device for proof of non-membership of a client in the group;

B. making a dynamic decision on whether the client is not a member of the group; and

C. issuing to the network device, if the server decides that the client is not a member of the group, a group non-membership certificate proving that the client is not a member of the group.

38. The method of claim 37 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group non-membership certificate.

39. The method of claim 37 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group non-membership certificate and authorizing client access to the resource.

40. A method of operating an on-line server on a computer network, said server associated with a group and performing the steps of:

A. receiving a request from a network device for proof of non-membership of a client in the group;

B. making a dynamic decision on whether the client is not a member of the group; and

C. issuing to the network device, if the server decides that the client is not a member of the group, a group membership list proving that the client is not a member of the group.

41. The method of claim 40 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

42. The method of claim 40 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership list and authorizing client access to the resource.

43. An on-line server on a computer network, said server associated with a group and comprised of:

A. means for receiving a request from a network device for proof of membership of a client in the group;

B. means for making a dynamic decision on whether the client is a member of the group; and

C. means for issuing to the network device, if the server decides that the client is a member of the group, a group membership certificate proving that the client is a member of the group.

44. The on-line server of claim 43 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership certificate.

45. The on-line server of claim 43 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership certificate and authorizing client access to the resource.

46. An on-line server on a computer network, said server associated with a group and comprised of:

A. means for receiving a request from a network device for proof of membership of a client in the group;

B. means for making a dynamic decision on whether the client is a member of the group; and

C. means for issuing to the network device, if the server decides that the client is a member of the group, a group membership list proving that the client is a member of the group.

47. The on-line server of claim 46 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

48. The on-line server of claim 46 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership list and authorizing client access to the resource.

49. An on-line server on a computer network, said server associated with a group and comprised of:

A. means for receiving a request from a network device for proof of non-membership of a client in the group;

B. means for making a dynamic decision on whether the client is not a member of the group; and

C. means for issuing to the network device, if the server decides that the client is not a member of the group, a group non-membership certificate proving that the client is not a member of the group.

50. The on-line server of claim 49 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group non-membership certificate.

51. The on-line server of claim 49 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group non-membership certificate and authorizing client access to the resource.

52. An on-line server on a computer network, said server associated with a group and comprised of:

A. means for receiving a request from a network device for proof of non-membership of a client in the group;

B. means for making a dynamic decision on whether the client is not a member of the group; and

C. means for issuing to the network device, if the server decides that the client is not a member of the group, a group membership list proving that the client is not a member of the group.

53. The on-line server of claim 52 wherein the network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

54. The on-line server of claim 52 wherein the network device is a resource server receiving a request from a client seeking access to a resource on the resource server, said resource server validating the group membership list and authorizing client access to the resource.

55. A computer data signal embodied in a carrier wave and representing a sequence of instructions that, when executed by a processor in a network device associated with a group, configures the network device to operate as an on-line server that:

A. receives a request from a second network device for proof of membership of a client in the group;

B. makes a dynamic decision on whether the client is a member of the group; and

C. issues to the second network device, if the on-line server decides that the client is a member of the group, a group membership certificate proving that the client is a member of the group.

56. The computer data signal of claim 55 wherein the second network device is the client, said client subsequently presenting to a resource server a request for access to a

resource on the resource server, said request including the group membership certificate.

57. The computer data signal of claim 55 wherein the second network device is a resource server, said resource server receiving a request from a client seeking access to a resource on the resource server, validating the group membership certificate, and authorizing client access to the resource.

58. A computer data signal embodied in a carrier wave and representing a sequence of instructions that, when executed by a processor in a network device associated with a group, configures the network device to operate as an on-line server that:

A. receives a request from a second network device for proof of membership of a client in the group;

B. makes a dynamic decision on whether the client is a member of the group; and

C. issues to the second network device, if the on-line server decides that the client is a member of the group, a group membership list proving that the client is a member of the group.

59. The computer data signal of claim 58 wherein the second network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

60. The computer data signal of claim 58 wherein the second network device is a resource server, said resource server receiving a request from a client seeking access to a resource on the resource server, validating the group membership list, and authorizing client access to the resource.

61. A computer data signal embodied in a carrier wave and representing a sequence of instructions that, when executed by a processor in a network device associated with a group, configures the network device to operate as an on-line server that:

A. receives a request from a second network device for proof of non-membership of a client in the group;

B. makes a dynamic decision on whether the client is not a member of the group; and

C. issues to the second network device, if the on-line server decides that the client is not a member of the group, a group non-membership certificate proving that the client is not a member of the group.

62. The computer data signal of claim 61 wherein the second network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group non-membership certificate.

63. The computer data signal of claim 61 wherein the second network device is a resource server, said resource server receiving a request from a client seeking access to a resource on the resource server, validating the group non-membership certificate, and authorizing client access to the resource.

64. A computer data signal embodied in a carrier wave and representing a sequence of instructions that, when executed by a processor in a network device associated with a group, configures the network device to operate as an on-line server that:

A. receives a request from a second network device for proof of non-membership of a client in the group;

B. makes a dynamic decision on whether the client is not a member of the group; and

C. issues to the second network device, if the on-line server decides that the client is not a member of the group, a group membership list proving that the client is not a member of the group.

65. The computer data signal of claim 64 wherein the second network device is the client, said client subsequently presenting to a resource server a request for access to a resource on the resource server, said request including the group membership list.

66. The computer data signal of claim 64 wherein the second network device is a resource server, said resource server receiving a request from a client seeking access to a resource on the resource server, validating the group membership list, and authorizing client access to the resource.

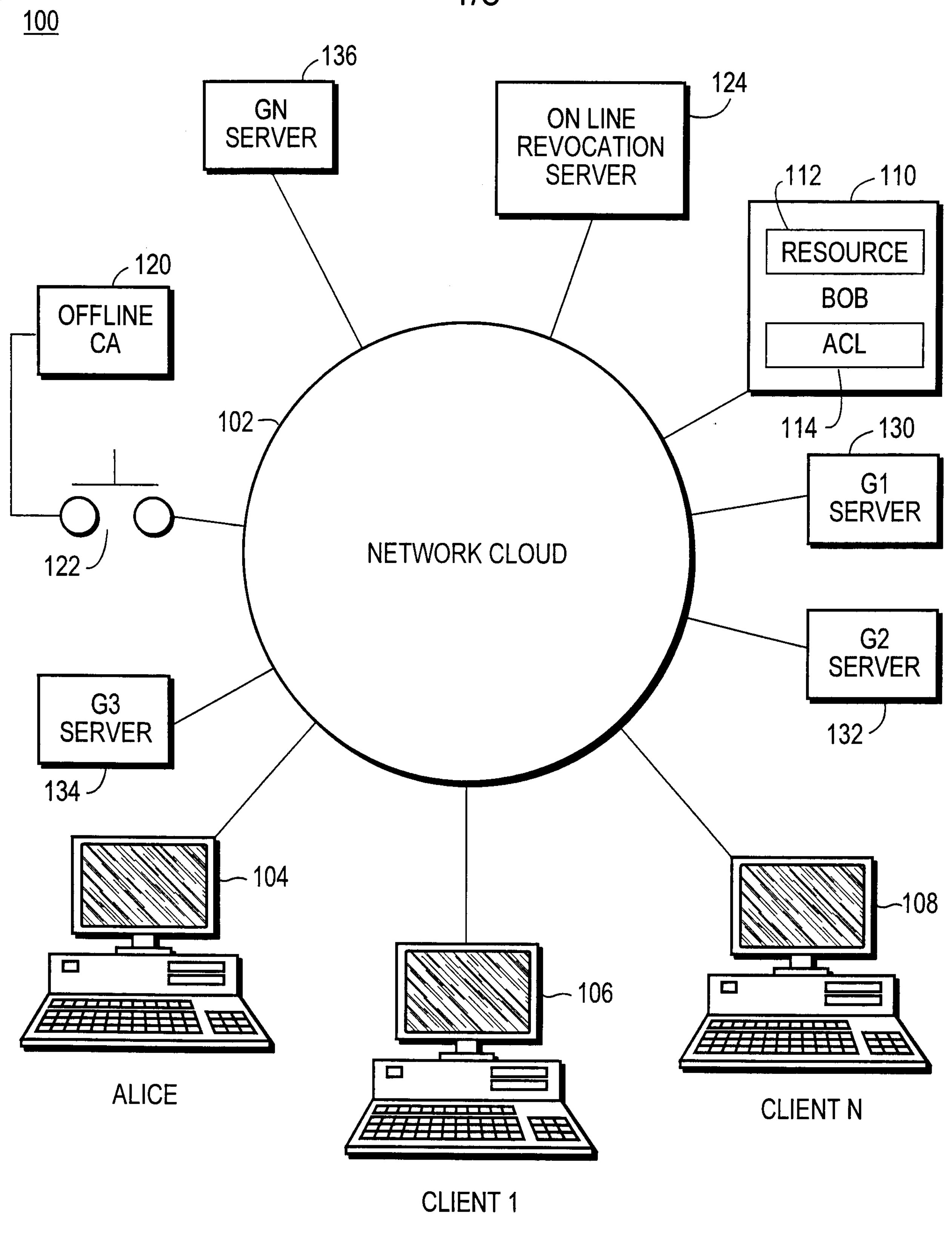
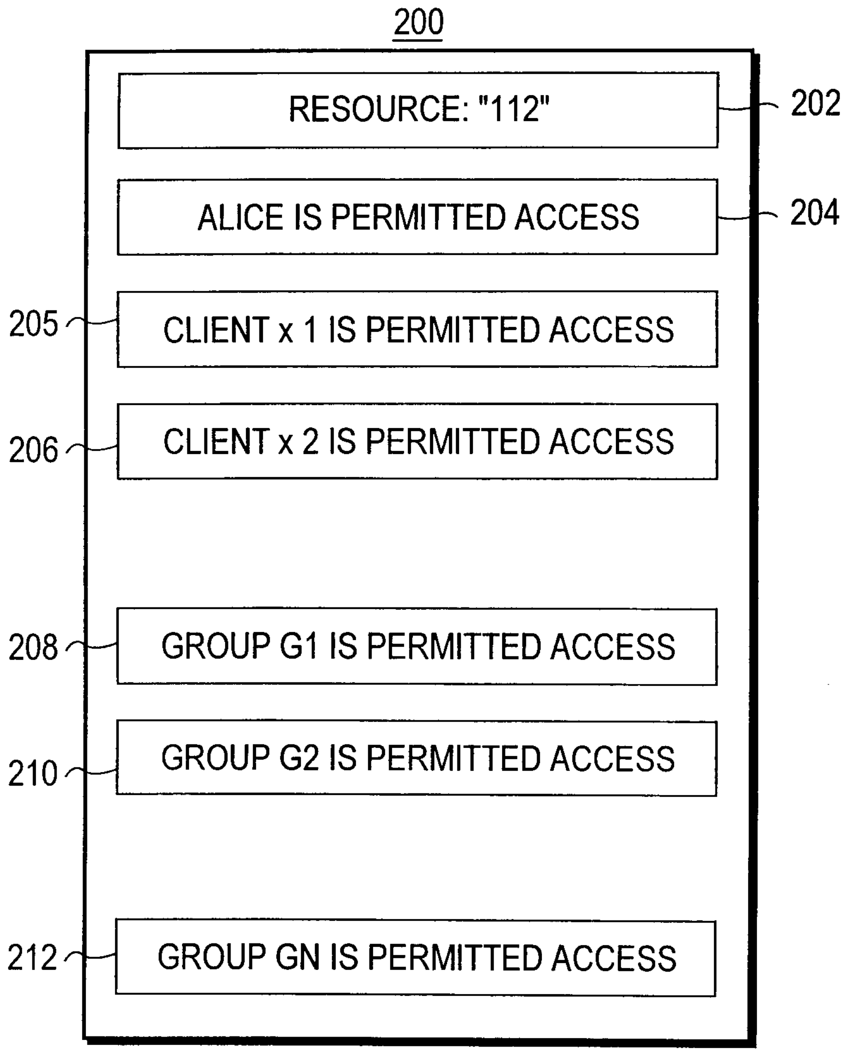
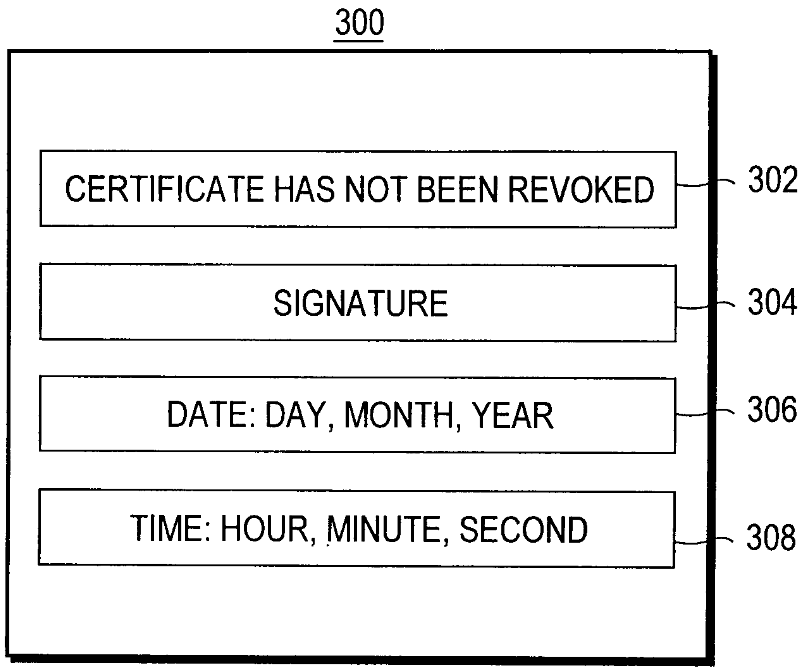

100
136
GN SERVER
ON LINE REVOCATION SERVER
124
112
110
RESOURCE
BOB
ACL
114
120
OFFLINE CA
102
130
G1 SERVER
122
NETWORK CLOUD
G2 SERVER
132
G3 SERVER
134
104
106
108
ALICE
CLIENT 1
CLIENT N

FIG. 1


200
RESOURCE: "112"
ALICE IS PERMITTED ACCESS
CLIENT x 1 IS PERMITTED ACCESS
CLIENT x 2 IS PERMITTED ACCESS
GROUP G1 IS PERMITTED ACCESS
GROUP G2 IS PERMITTED ACCESS
GROUP GN IS PERMITTED ACCESS
202
204
205
206
208
210
212

ACL OF RESOURCE ON SERVER BOB

FIG. 2



ALICE'S CERTIFICATE OF NON-REVOCATION

FIG. 3

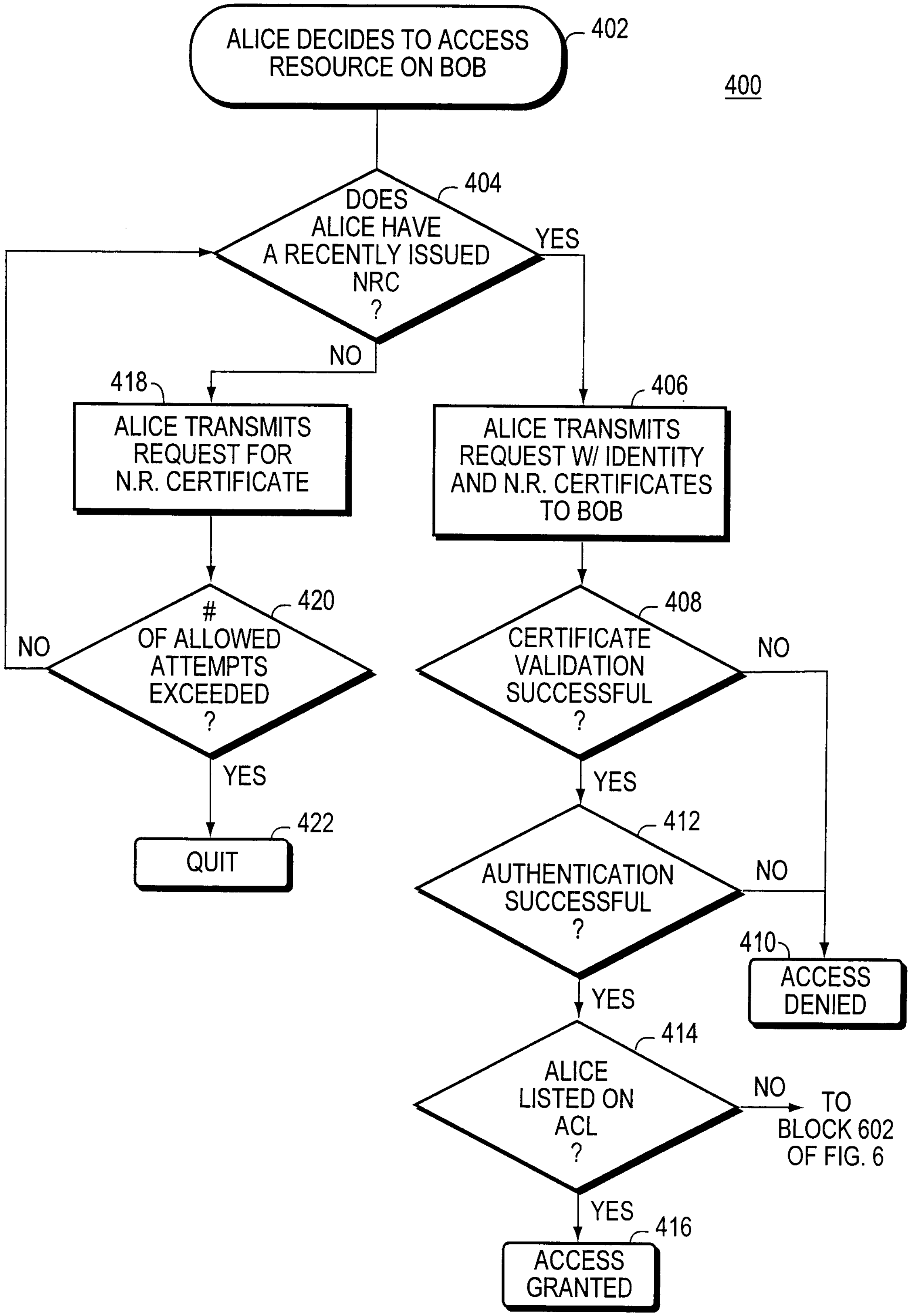
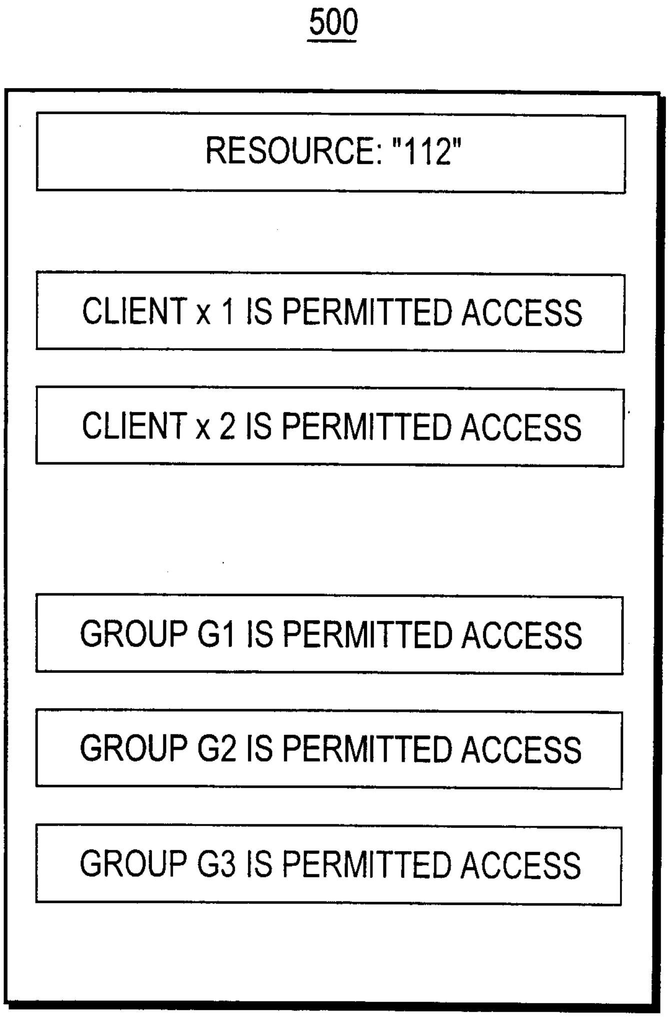

ALICE DECIDES TO ACCESS RESOURCE ON BOB
402
400
DOES ALICE HAVE A RECENTLY ISSUED NRC ?
404
YES
NO
418
ALICE TRANSMITS REQUEST FOR N.R. CERTIFICATE
406
ALICE TRANSMITS REQUEST W/ IDENTITY AND N.R. CERTIFICATES TO BOB
# OF ALLOWED ATTEMPTS EXCEEDED ?
420
NO
YES
422
QUIT
CERTIFICATE VALIDATION SUCCESSFUL ?
408
NO
YES
AUTHENTICATION SUCCESSFUL ?
412
NO
410
ACCESS DENIED
YES
ALICE LISTED ON ACL ?
414
NO
TO BLOCK 602 OF FIG. 6
YES
416
ACCESS GRANTED

FIG. 4


500
RESOURCE: "112"
CLIENT x 1 IS PERMITTED ACCESS
CLIENT x 2 IS PERMITTED ACCESS
GROUP G1 IS PERMITTED ACCESS
GROUP G2 IS PERMITTED ACCESS
GROUP G3 IS PERMITTED ACCESS

ACL OF RESOURCE ON SERVER BOB

FIG. 5

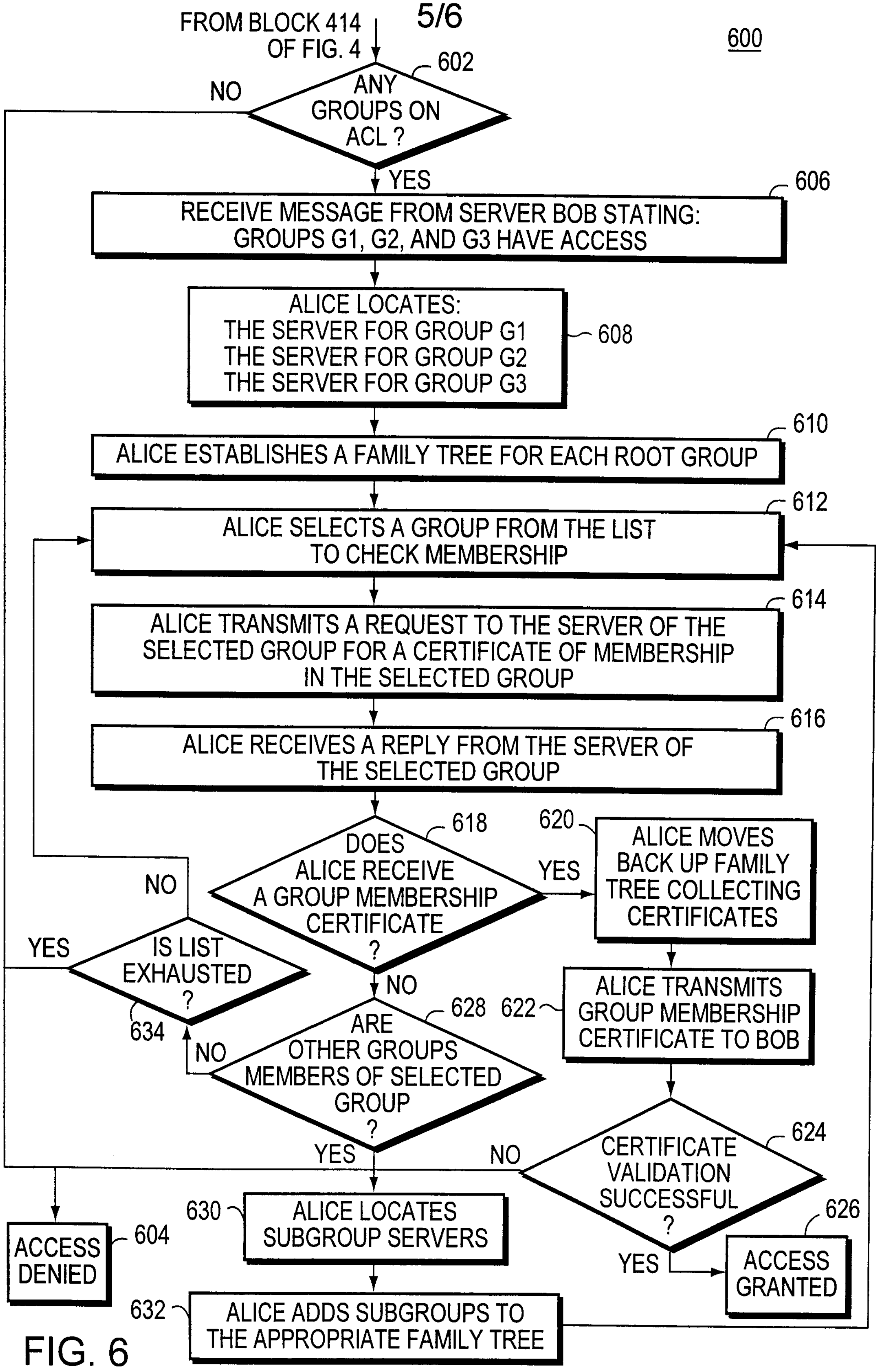

600
FROM BLOCK 414 OF FIG. 4
602
ANY GROUPS ON ACL ?
NO
YES
606
RECEIVE MESSAGE FROM SERVER BOB STATING: GROUPS G1, G2, AND G3 HAVE ACCESS
608
ALICE LOCATES: THE SERVER FOR GROUP G1 THE SERVER FOR GROUP G2 THE SERVER FOR GROUP G3
610
ALICE ESTABLISHES A FAMILY TREE FOR EACH ROOT GROUP
612
ALICE SELECTS A GROUP FROM THE LIST TO CHECK MEMBERSHIP
614
ALICE TRANSMITS A REQUEST TO THE SERVER OF THE SELECTED GROUP FOR A CERTIFICATE OF MEMBERSHIP IN THE SELECTED GROUP
616
ALICE RECEIVES A REPLY FROM THE SERVER OF THE SELECTED GROUP
618
DOES ALICE RECEIVE A GROUP MEMBERSHIP CERTIFICATE ?
YES
620
ALICE MOVES BACK UP FAMILY TREE COLLECTING CERTIFICATES
NO
YES
IS LIST EXHAUSTED ?
634
NO
628
ARE OTHER GROUPS MEMBERS OF SELECTED GROUP ?
NO
622
ALICE TRANSMITS GROUP MEMBERSHIP CERTIFICATE TO BOB
624
CERTIFICATE VALIDATION SUCCESSFUL ?
YES
NO
630
ALICE LOCATES SUBGROUP SERVERS
604
ACCESS DENIED
626
ACCESS GRANTED
YES
632
ALICE ADDS SUBGROUPS TO THE APPROPRIATE FAMILY TREE

FIG. 6

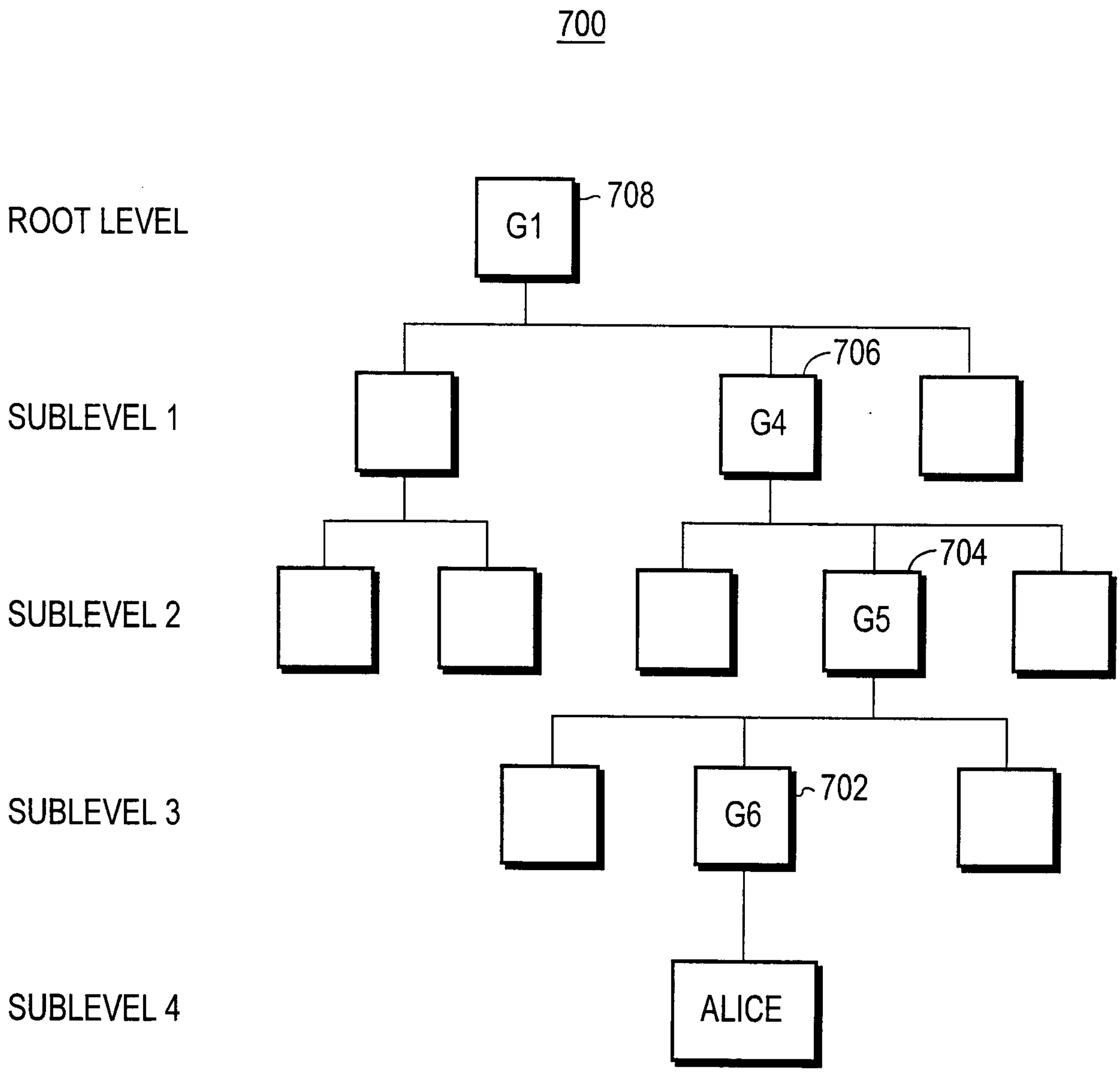

700
ROOT LEVEL
G1
708
SUBLEVEL 1
G4
706
SUBLEVEL 2
G5
704
SUBLEVEL 3
G6
702
SUBLEVEL 4
ALICE

FIG. 7

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 00/12052

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 220 604 A (GASSER MORRIE ET AL) 15 June 1993 (1993-06-15) abstract column 1 -column 24 figures 4,10-14 ---	1-66

-/--

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search 8 August 2000	Date of mailing of the international search report 16/08/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Authorized officer Jacobs, P

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 00/12052

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 173 939 A (ABADI MARTIN ET AL) 22 December 1992 (1992-12-22)	1-5,7,8, 16-20, 22,23, 31,37, 43,49, 55,61
A		6,9-15, 21, 24-30, 32-36, 38-42, 44-48, 50-54, 56-60, 62-66
	column 6, line 50 -column 8, line 10 ---	
X	WO 98 10381 A (SHEAR VICTOR H ;WEBER ROBERT (US); WIE DAVID M VAN (US); INTERTRUS) 12 March 1998 (1998-03-12)	1,3,16, 18, 31-33, 43-45, 55-57
A		4-6, 10-12, 19-21, 25-27, 34-36, 46-48, 58-60
	page 23, line 8 -page 24, line 3 page 71, line 5 -page 72, line 12 page 191 -page 224, line 8 -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

Interr nal Application No
PCT/US 00/12052

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5220604	A	15-06-1993	NONE		
US 5173939	A	22-12-1992	US	5315657 A	24-05-1994
			WO	9309499 A	13-05-1993
WO 9810381	A	12-03-1998	AU	3205797 A	05-12-1997
			AU	7106296 A	26-03-1998
			CN	1225739 A	11-08-1999
			EP	0974129 A	26-01-2000
			EP	0898777 A	03-03-1999
			WO	9743761 A	20-11-1997