INFS 767 Fall 2003

RBAC Architectures and Mechanisms

Prof. Ravi Sandhu

LAYERS AND LAYERS

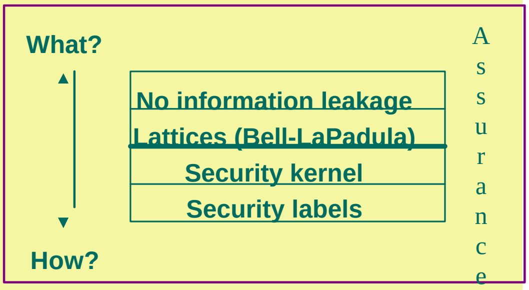
- Multics rings
- Layered abstractions
- Waterfall model
- Network protocol stacks
- Napolean layers
- RoFi layers
- OM-AM
- etcetera

AUTHORIZATION, TRUST AND RISK

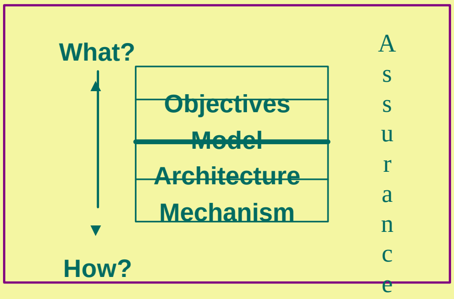
- Information security is fundamentally about managing
  - authorization and
  - trust

  so as to manage risk

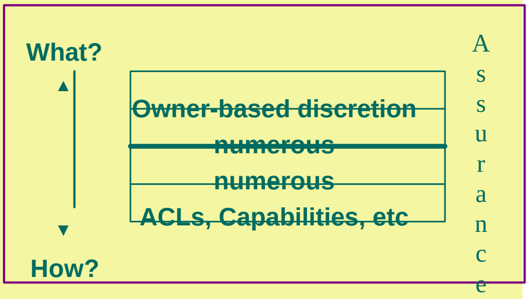
OM-AM AND MANDATORY ACCESS CONTROL (MAC)



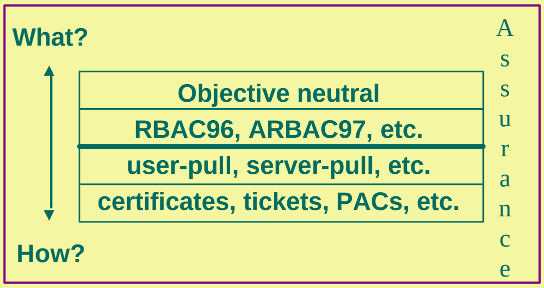
THE OM-AM WAY



OM-AM AND DISCRETIONARY ACCESS CONTROL (DAC)



OM-AM AND ROLE-BASED ACCESS CONTROL (RBAC)


What?
Objective neutral
RBAC96, ARBAC97, etc.
user-pull, server-pull, etc.
certificates, tickets, PACs, etc.
How?
Assurance

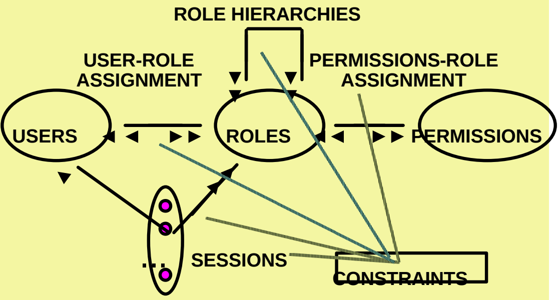
DISTRIBUTED RBAC (DRBAC) CASE STUDY

- Each simulation model has a security administrator role authorized to carry out these administrative tasks
- A simulation model can assign permissions to a role X at any time
  - even if X is previously unused in that simulation model
- Consequently any simulation model can revoke any user from any role!

DISTRIBUTED RBAC (DRBAC) CASE STUDY

- Approximately a dozen physical sites
- Approximately 2-3 simulation models/site
- Fewer than 100 roles structured in a very shallow hierarchy
  - A subset of roles is used in any single simulation model
- Fewer than 100 users
- A user uses only one role at a time
  - Convenient but not critical
- Moderate rate of change

RBAC3



DISTRIBUTED RBAC (DRBAC) CASE STUDY

- Permission-role assignment
  - Locally determined at each simulation model
- User-role assignment
  - A user can be assigned to a role if and only if all simulation models using that role agree
  - A user is revoked from a role if and only if any simulation model using that role revokes the user

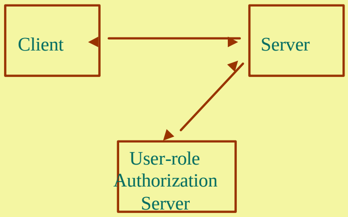
MODEL CUSTOMIZATION

- Each session has a single role
- SM = {sm1, …, smk}, simulation models
- OP = {op1, …, opl}, operations
- P= SM X OP, permissions
- SMA = {sma1, …, smk}, administrative roles
- R Ç SMA = Æ
- Admin: SM « SMA

MODEL CUSTOMIZATION

- Can formalize the administrative rules given earlier
- For each simulation model designate a unique user to be the chief security administrator who is authorized to assign and revoke users from the security administrator role for that model

SERVER-PULL


Client

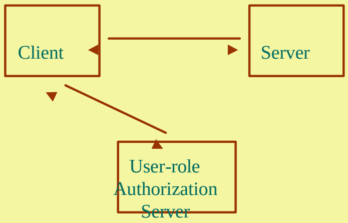
Server

User-role Authorization Server

DRBAC ARCHITECTURES

- Permission-role
  - Enforced locally at each simulation model
- Permission-role administration
  - Enforced locally at each simulation model
  - May need to communicate to other simulation models
- User-role
  - See following slides
- User-role administration
  - Centralized or decentralized

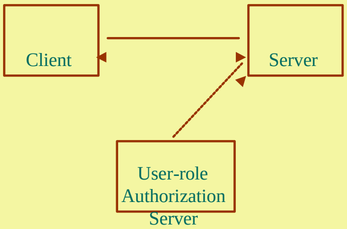
USER-PULL


Client

Server

User-role Authorization Server

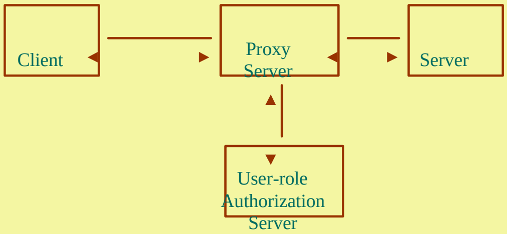
SERVER MIRROR


Client

Server

User-role Authorization Server

PROXY-BASED

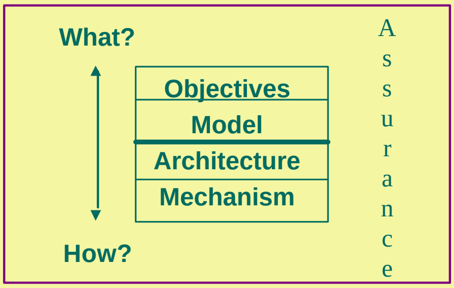

Client

Proxy Server

Server

User-role Authorization Server

THE OM-AM WAY



What?

Objectives

Model

Architecture

Mechanism

How?

Assurance

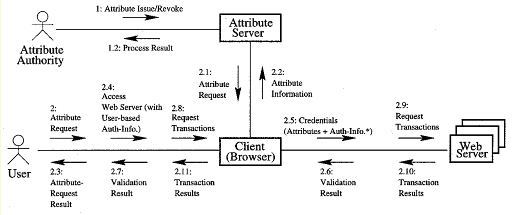
Secure Attribute Services on the Web

- WWW (World Wide Web)
  - widely used for electronic commerce and business
  - supports synthesis of technologies
  - mostly, Web servers use identity-based access control
    - scalability problem

Background

- An attribute
  - a particular property of an entity
    - e.g., role, identity, SSN, clearance, etc.
- If attributes are provided securely,
  - Web servers can use those attributes
    - e.g., authentication, authorization, access control, electronic commerce, etc.
- A successful marriage of the Web and secure attribute services is required

User-Pull Architecture

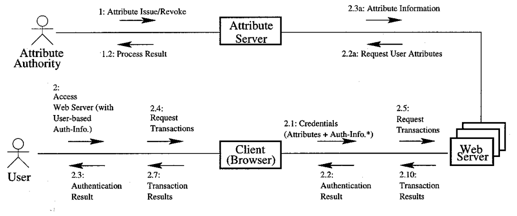

1: Attribute Issue/Revoke
1.2: Process Result
Attribute Authority
Attribute Server
2.1: Attribute Request
2.2: Attribute Information
2: Attribute Request
2.4: Access Web Server (with User-based Auth-Info.)
2.8: Request Transactions
2.5: Credentials (Attributes + Auth-Info.*)
2.9: Request Transactions
User
Client (Browser)
Web Server
2.3: Attribute-Request Result
2.7: Validation Result
2.11: Transaction Results
2.6: Validation Result
2.10: Transaction Results

*Authentication Information can be either user-based or host-based.

User-Pull Architecture

- Each user
  - pulls appropriate attributes from the Attribute Server
  - presents attributes and authentication information to Web servers
- Each Web server
  - requires both identification and attributes from users
- High performance
  - No new connections for attributes

Server-Pull Architecture

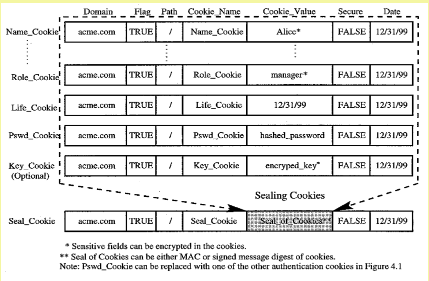

1: Attribute Issue/Revoke
1.2: Process Result
Attribute Authority
Attribute Server
2.3a: Attribute Information
2.2a: Request User Attributes
2: Access Web Server (with User-based Auth-Info.)
2.4: Request Transactions
2.1: Credentials (Attributes + Auth-Info.*)
2.5: Request Transactions
User
Client (Browser)
Web Server
2.3: Authentication Result
2.7: Transaction Results
2.2: Authentication Result
2.10: Transaction Results

*Authentication Information can be either user-based or host-based.

Related Technologies

- Cookies
  - in widespread current use for maintaining state of HTTP
  - becoming standard
  - not secure
- Public-Key Certificates (X.509)
  - support security on the Web based on PKI
  - standard
  - simply, bind users to keys
  - have the ability to be extended

Secure Cookies on the Web



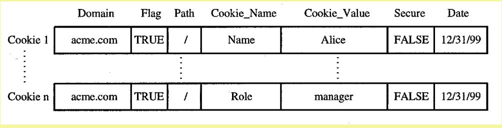
	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
Name_Cookie	acme.com	TRUE	/	Name_Cookie	Alice*	FALSE	12/31/99
⋮			⋮		⋮		
Role_Cookie	acme.com	TRUE	/	Role_Cookie	manager*	FALSE	12/31/99
Life_Cookie	acme.com	TRUE	/	Life_Cookie	12/31/99	FALSE	12/31/99
Pswd_Cookie	acme.com	TRUE	/	Pswd_Cookie	hashed_password	FALSE	12/31/99
Key_Cookie (Optional)	acme.com	TRUE	/	Key_Cookie	encryped_key*	FALSE	12/31/99
Seal_Cookie	acme.com	TRUE	/	Seal_Cookie	Seal_of_Cookies**	FALSE	12/31/99

* Sensitive fields can be encrypted in the cookies.

** Seal of Cookies can be either MAC or signed message digest of cookies.

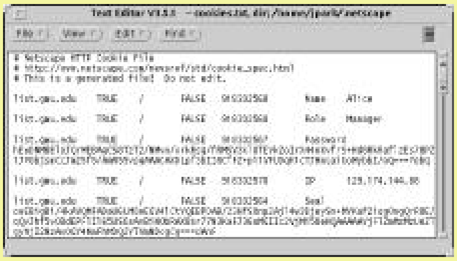
Note: Pswd_Cookie can be replaced with one of the other authentication cookies in Figure 4.1

Cookies



	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
Cookie 1	acme.com	TRUE	/	Name	Alice	FALSE	12/31/99
⋮			⋮		⋮		
Cookie n	acme.com	TRUE	/	Role	manager	FALSE	12/31/99

A Set of Secure Cookies



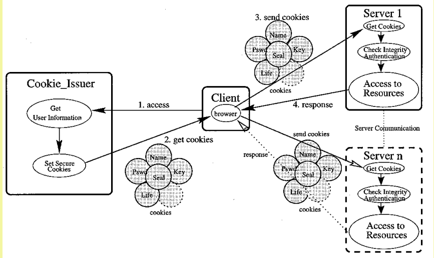
Text Editor V3.5.0 – cookies.txt, dir; /home/jpark/.netscape
File
View
Edit
Find

```
# Netscape HTTP Cookie File
# http://www.netscape.com/newsref/std/cookie_spec.html
# This is a generated file!  Do not edit.

list.gmu.edu    TRUE    /       FALSE   [illegible]       Name    Alice

list.gmu.edu    TRUE    /       FALSE   [illegible]       Role    Manager

list.gmu.edu    TRUE    /       FALSE   [illegible]       Password
[illegible]

list.gmu.edu    TRUE    /       FALSE   [illegible]       IP      129.174.144.88

list.gmu.edu    TRUE    /       FALSE   [illegible]       Seal
[illegible]
```

Security Threats to Cookies

- Cookies are not secure
  - No authentication
  - No integrity
  - No confidentiality
- can be easily attacked by
  - Network Security Threats
  - End-System Threats
  - Cookie Harvesting Threats

How to Use Secure Cookies

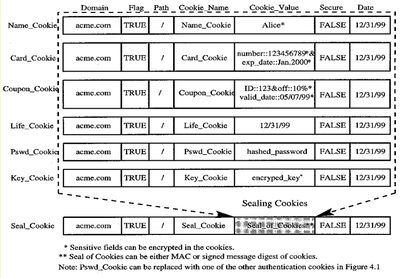


Pswd_Cookie can be replaced with one of the other authentication cookies in Figure 4.1

Applications of Secure Cookies

- User Authentication
- Electronic Transaction
- Eliminating Single-Point Failure
- Pay-per-Access
- Attribute-based Access Control

Secure Cookies for Electronic Transactions



	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
Name_Cookie	acme.com	TRUE	/	Name_Cookie	Alice*	FALSE	12/31/99
Card_Cookie	acme.com	TRUE	/	Card_Cookie	number::123456789*& exp_date::Jan.2000*	FALSE	12/31/99
Coupon_Cookie	acme.com	TRUE	/	Coupon_Cookie	ID::123&off::10%* valid_date::05/07/99*	FALSE	12/31/99
Life_Cookie	acme.com	TRUE	/	Life_Cookie	12/31/99	FALSE	12/31/99
Pswd_Cookie	acme.com	TRUE	/	Pswd_Cookie	hashed_password	FALSE	12/31/99
Key_Cookie	acme.com	TRUE	/	Key_Cookie	encryped_key*	FALSE	12/31/99

Sealing Cookies

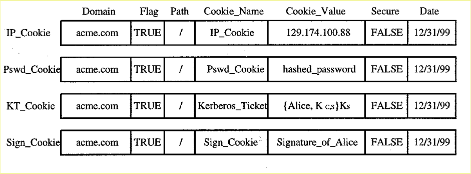
Seal_Cookie	acme.com	TRUE	/	Seal_Cookie	Seal_of_Cookies**	FALSE	12/31/99

* Sensitive fields can be encrypted in the cookies.

** Seal of Cookies can be either MAC or signed message digest of cookies.

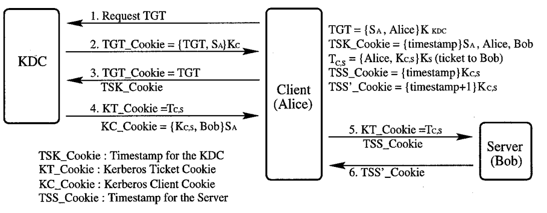
Note: Pswd_Cookie can be replaced with one of the other authentication cookies in Figure 4.1

Authentication Cookies



	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
IP_Cookie	acme.com	TRUE	/	IP_Cookie	129.174.100.88	FALSE	12/31/99
Pswd_Cookie	acme.com	TRUE	/	Pswd_Cookie	hashed_password	FALSE	12/31/99
KT_Cookie	acme.com	TRUE	/	Kerberos_Ticket	$\{Alice, K_{c,s}\}K_s$	FALSE	12/31/99
Sign_Cookie	acme.com	TRUE	/	Sign_Cookie	Signature_of_Alice	FALSE	12/31/99

Kerberos-Based Authentication by Secure Cookies



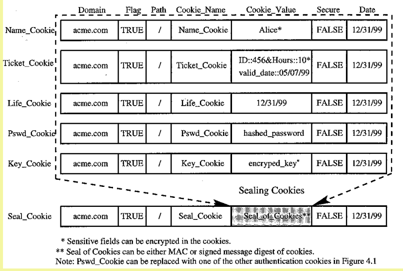
TGT = $\{S_A, Alice\}K_{KDC}$
TSK_Cookie = $\{timestamp\}S_A$, Alice, Bob
$T_{C,S}$ = $\{Alice, K_{C,S}\}K_S$ (ticket to Bob)
TSS_Cookie = $\{timestamp\}K_{C,S}$
TSS'_Cookie = $\{timestamp+1\}K_{C,S}$

TSK_Cookie : Timestamp for the KDC
KT_Cookie : Kerberos Ticket Cookie
KC_Cookie : Kerberos Client Cookie
TSS_Cookie : Timestamp for the Server

Server-Pull Architecture

- Each user
  - presents only authentication information to Web servers
- Each Web server
  - pulls users' attributes from the Attribute Server
- Authentication information and attribute do not go together
- More convenient for users
- Less convenient for Web servers

Secure Cookies for Pay-Per-Access



	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
Name_Cookie	acme.com	TRUE	/	Name_Cookie	Alice*	FALSE	12/31/99
Ticket_Cookie	acme.com	TRUE	/	Ticket_Cookie	ID::456&Hours::10* valid_date::05/07/99	FALSE	12/31/99
Life_Cookie	acme.com	TRUE	/	Life_Cookie	12/31/99	FALSE	12/31/99
Pswd_Cookie	acme.com	TRUE	/	Pswd_Cookie	hashed_password	FALSE	12/31/99
Key_Cookie	acme.com	TRUE	/	Key_Cookie	encryped_key*	FALSE	12/31/99

Sealing Cookies

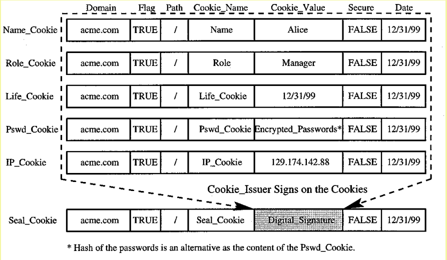
Seal_Cookie	acme.com	TRUE	/	Seal_Cookie	Seal_of_Cookies**	FALSE	12/31/99

* Sensitive fields can be encrypted in the cookies.

** Seal of Cookies can be either MAC or signed message digest of cookies.

Note: Pswd_Cookie can be replaced with one of the other authentication cookies in Figure 4.1

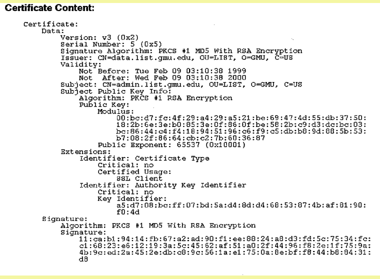
Secure Cookies for RBAC



	Domain	Flag	Path	Cookie_Name	Cookie_Value	Secure	Date
Name_Cookie	acme.com	TRUE	/	Name	Alice	FALSE	12/31/99
Role_Cookie	acme.com	TRUE	/	Role	Manager	FALSE	12/31/99
Life_Cookie	acme.com	TRUE	/	Life_Cookie	12/31/99	FALSE	12/31/99
Pswd_Cookie	acme.com	TRUE	/	Pswd_Cookie	Encrypted_Passwords*	FALSE	12/31/99
IP_Cookie	acme.com	TRUE	/	IP_Cookie	129.174.142.88	FALSE	12/31/99
Seal_Cookie	acme.com	TRUE	/	Seal_Cookie	Digital_Signature	FALSE	12/31/99

* Hash of the passwords is an alternative as the content of the Pswd_Cookie.

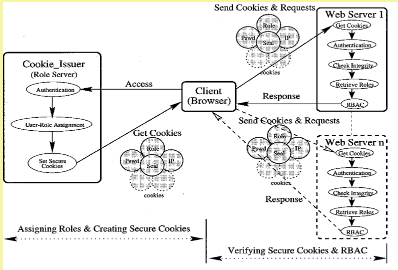
X.509 Certificate



Certificate Content:

```
    Certificate:
        Data:
            Version: v3 (0x2)
            Serial Number: 5 (0x5)
            Signature Algorithm: PKCS #1 MD5 With RSA Encryption
            Issuer: CN=data.list.gmu.edu, OU=LIST, O=GMU, C=US
            Validity:
                Not Before: Tue Feb 09 03:10:38 1999
                Not  After: Wed Feb 09 03:10:38 2000
            Subject: CN=admin.list.gmu.edu, OU=LIST, O=GMU, C=US
            Subject Public Key Info:
                Algorithm: PKCS #1 RSA Encryption
                Public Key:
                    Modulus:
                        00:bc:d7:fc:4f:29:a4:29:a5:21:be:69:47:4d:55:db:37:50:
                        18:2b:6e:3e:b0:85:3e:0f:86:0f:be:58:2b:c9:d3:dc:bc:03:
                        bc:86:44:c4:f4:18:94:51:96:c6:f9:c5:db:b8:9d:88:5b:53:
                        b7:08:2f:86:64:cb:c2:7b:60:36:87
                    Public Exponent: 65537 (0x10001)
            Extensions:
                Identifier: Certificate Type
                    Critical: no
                    Certified Usage:
                        SSL Client
                Identifier: Authority Key Identifier
                    Critical: no
                    Key Identifier:
                        a5:d7:08:bc:ff:07:bd:5a:d4:8d:d4:68:53:87:4b:af:81:90:
                        f0:4d
        Signature:
            Algorithm: PKCS #1 MD5 With RSA Encryption
            Signature:
                11:ca:b1:94:14:fb:67:a2:ad:90:f1:ee:88:24:a8:d3:fd:5c:75:34:fc:
                c1:68:23:e6:12:19:3a:5c:45:62:af:51:a0:2f:44:96:f8:2e:1f:75:9a:
                4b:9c:ed:2a:45:2e:db:c8:9c:56:1a:e1:75:0a:8e:bf:f8:44:b8:84:31:
                d8
```

RBAC on the Web by Secure Cookies



Smart Certificates

- **Short-Lived Lifetime**
  - **More secure**
    - **typical validity period for X.509 is months (years)**
    - **users may leave copies of the corresponding keys behind**
    - **the longer-lived certificates have a higher probability of being attacked**
  - **No Certificate Revocation List (CRL)**
    - **simple and less expensive PKI**

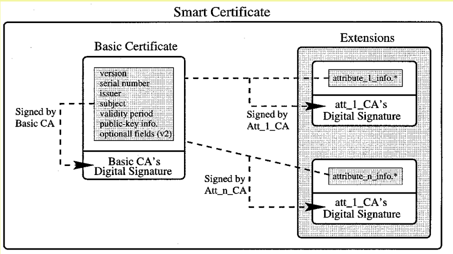
X.509 Certificate

- **Digitally signed by a certificate authority**
  - **to confirm the information in the certificate belongs to the holder of the corresponding private key**
- **Contents**
  - **version, serial number, subject, validity period, issuer, optional fields (v2)**
  - **subject's public key and algorithm info.**
  - **extension fields (v3)**
  - **digital signature of CA**
- **Binding users to keys**
- **Certificate Revocation List (CRL)**

Smart Certificates

- **Containing Attributes Securely**
  - **Web servers can use secure attributes for their purposes**
  - **Each authority has independent control on the corresponding information**
    - **basic certificate (containing identity information)**
    - **each attribute can be added, changed, revoked, or re-issued by the appropriate authority**
      - e.g., role, credit card number, clearance, etc.
  - **Short-lived certificate can remove CRLs**

Separate CAs in a Certificate



* attribute info.: attributes, attribute issuer, validity period of attributes, etc.

Applications of Smart Certificates

- On-Duty Control
- Compatible with X.509
- User Authentication
- Electronic Transaction
- Eliminating Single-Point Failure
- Pay-per-Access
- Attribute-based Access Control

Smart Certificates

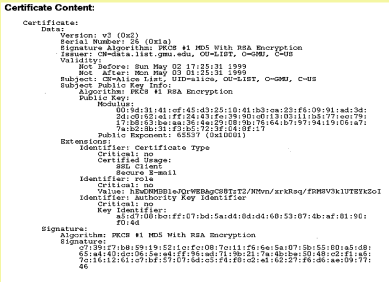
- Postdated Certificates
  - The certificate becomes valid at some time in the future
  - possible to make a smart certificate valid for a set of duration
  - supports convenience
- Confidentiality
  - Sensitive information can be
    - encrypted in smart certificates
      - e.g. passwords, credit card numbers, etc.

Injecting RBAC to Secure a Web-based Workflow System

Gail-Joon Ahn and Ravi Sandhu
George Mason University

Myong Kang and Joon Park
Naval Research Laboratory

A Smart Certificate



Certificate Content:

```
    Certificate:
        Data:
            Version: v3 (0x2)
            Serial Number: 26 (0x1a)
            Signature Algorithm: PKCS #1 MD5 With RSA Encryption
            Issuer: CN=data.list.gmu.edu, OU=LIST, O=GMU, C=US
            Validity:
                Not Before: Sun May 02 17:25:31 1999
                Not  After: Mon May 03 01:25:31 1999
            Subject: CN=Alice List, UID=alice, OU=LIST, O=GMU, C=US
            Subject Public Key Info:
                Algorithm: PKCS #1 RSA Encryption
                Public Key:
                    Modulus:
                        00:9d:31:41:cf:45:d3:25:10:41:b3:ca:23:f6:09:91:ad:3d:
                        2d:c0:62:e1:ff:24:43:fe:39:90:c0:13:03:11:b5:77:ec:79:
                        17:b8:63:be:aa:36:4e:29:08:9b:76:64:b7:97:94:19:06:a7:
                        7a:b2:8b:31:f3:b5:72:3f:04:8f:17
                    Public Exponent: 65537 (0x10001)
            Extensions:
                Identifier: Certificate Type
                    Critical: no
                    Certified Usage:
                        SSL Client
                        Secure E-mail
                Identifier: role
                    Critical: no
                    Value: hEwDNMBBleJQrWEBAgCS8TzT2/NMvn/xrkRsq/fRMSV3klUTEYkZoI
                Identifier: Authority Key Identifier
                    Critical: no
                    Key Identifier:
                        a5:d7:08:bc:ff:07:bd:5a:d4:8d:d4:68:53:87:4b:af:81:90:
                        f0:4d
        Signature:
            Algorithm: PKCS #1 MD5 With RSA Encryption
            Signature:
                c7:39:f7:b8:59:19:52:1c:fc:08:7c:11:f6:6e:5a:07:5b:55:80:a5:d8:
                65:a4:40:dc:06:5e:e4:ff:96:ad:71:9b:21:7a:4b:be:50:48:c2:f1:a6:
                7c:16:12:61:c7:bf:57:07:6d:c5:f4:f8:c2:e1:62:27:f6:d6:ae:09:77:
                46
```

WORKFLOW MANAGEMENT SYSTEMS

- □ Control and coordinate processes that may be processed by different processing entities
- □ Received much attention
- □ Marriage with Web technology
- □ Minimal security services

OBJECTIVE

□ Inject role-based access control (RBAC) into an existing web-based workflow system

ROLE-BASED SECURE WORKFLOW SYSTEM

□ Workflow Design Tool

□ Workflow (WF) System

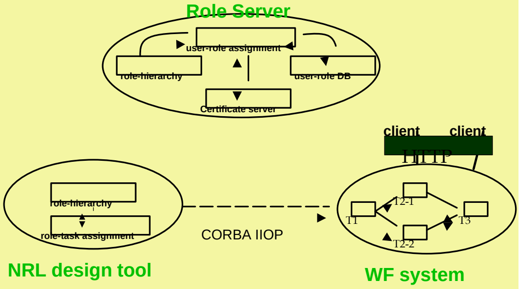
□ Role Server

WHY RBAC?

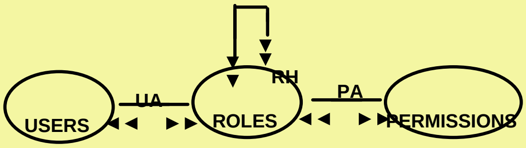
□ A mechanism which allows and promotes an organization-specific access control policy based on roles

□ Has become widely accepted as the proven technology

BASIC COMPONENTS



SIMPLIFIED RBAC MODEL

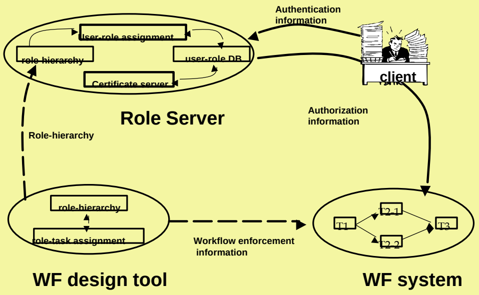


ARCHITECTURES

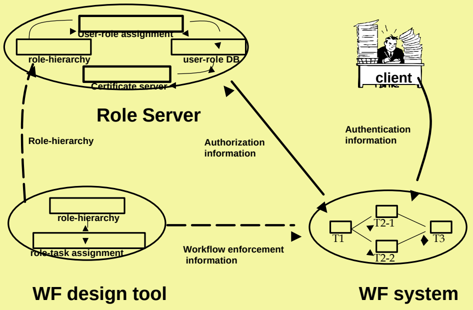
□ USER-PULL STYLE

□ SERVER-PULL STYLE

USER-PULL STYLE



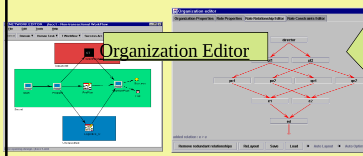
SERVER-PULL STYLE



NRL (Naval Research Lab.) DESIGN TOOL

- □ design workflow model
- □ create role and role hierarchies
- □ assign role to task
- □ exporting role hierarchies to role server

NRL DESIGN TOOL (Cont'd)



Organization Editor

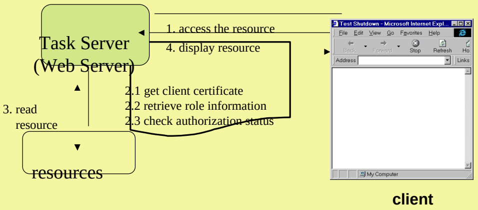
Platform: Windows NT, JDK1.2

```
<?xml version="1.0"?>
<!--URA    Revision: 1
  Mon Dec 07 15:59:28 EDT 1999-->
<!DOCTYPE Organization SYSTEM
  "../dtd/Organization.dtd">
<Organization id="Organization_URA">
<Name>URA</Name>
<Description></Description>
<Role id="director">
<Name>director</Name>
<Description></Description>
<Privileges></Privileges>
<LowRoleList>
 <RoleReference>
                <Link idref = "pl1"/>
 </RoleReference>
 <RoleReference>
                <Link idref = "pl2"/>
 </RoleReference>
</LowRoleList>
<HighRoleList>
</HighRoleList>
</Role>
<RoleReference>
```

WORKFLOW SYSTEM

- □ each task server is web server
- □ user should present client authentication certificate
- □ user's privilege is authorized by content of certificate (specially client's role information)

ROLE AUTHORIZATION ON WORKFLOW SYSTEM


Task Server
(Web Server)
1. access the resource
4. display resource
2.1 get client certificate
2.2 retrieve role information
2.3 check authorization status
3. read resource
resources
Test Shutdown - Microsoft Internet Expl...
File Edit View Go Favorites Help
Back
Forward
Stop
Refresh
Ho
Address
Links
My Computer
client

ROLE SERVER

- □ User Role Assignment
- □ Certificate Server

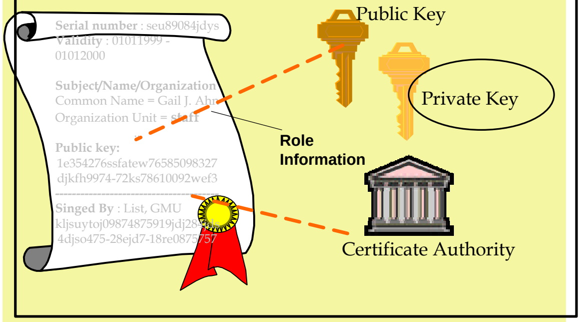
CERTIFICATE SERVER

- □ authenticate client
- □ retrieve client's role information from user-role database
- □ issue certificate with client's role information

USER ROLE ASSIGNMENT

- □ maintain role hierarchies and user database
- □ assign users to roles
- □ generate user-role database

X.509 CERTIFICATE



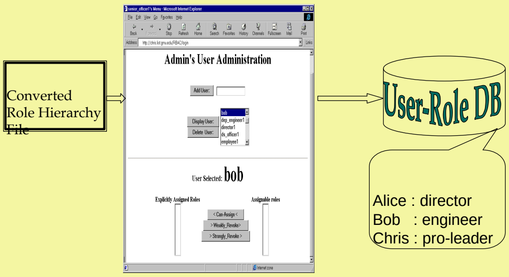
Serial number : seu89084jdys
Validity : 01011999 - 01012000

Subject/Name/Organization
Common Name = Gail J. Ahn
Organization Unit = staff

Public key:
1e354276ssfatew76585098327
djkfh9974-72ks78610092wef3

Singed By : List, GMU
kljsuytoj09874875919jdj28
4djso475-28ejd7-18re0875757

USER ROLE ASSIGNMENT (Cont'd)



Converted Role Hierarchy File
senior_officer1's Menu - Microsoft Internet Explorer
File Edit View Go Favorites Help
Back Forward Stop Refresh Home Search Favorites History Channels Fullscreen Mail Print
Address http://chris.list.gmu.edu/RBAC/login
Links
Add User:
Display User:
Delete User:
bob
dep_engineer1
director1
ds_officer1
employee1
< Can-Assign <
> Weakly_Revoke>
> Strongly_Revoke >
Internet zone
User-Role DB

Admin's User Administration

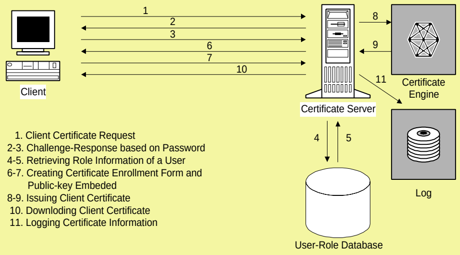
User Selected: bob

Explicitly Assigned Roles

Assignable roles

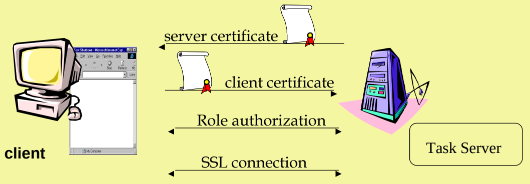
Alice : director
Bob : engineer
Chris : pro-leader

CERTIFICATE ISSUE



1. Client Certificate Request
2-3. Challenge-Response based on Password
4-5. Retrieving Role Information of a User
6-7. Creating Certificate Enrollment Form and Public-key Embeded
8-9. Issuing Client Certificate
10. Downloding Client Certificate
11. Logging Certificate Information

CERTIFICATE AUTHORIZATION OVER SSL



server certificate

client certificate

Role authorization

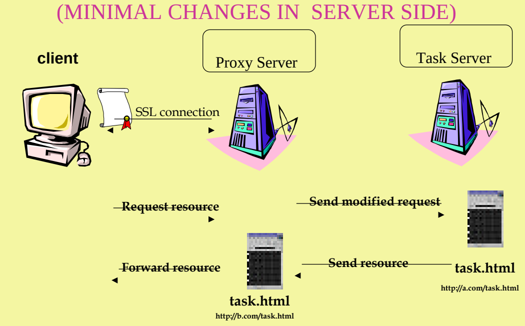
SSL connection

client

Task Server

REVERSE PROXYING

(MINIMAL CHANGES IN SERVER SIDE)



client

Proxy Server

Task Server

SSL connection

Request resource

Send modified request

Forward resource

Send resource

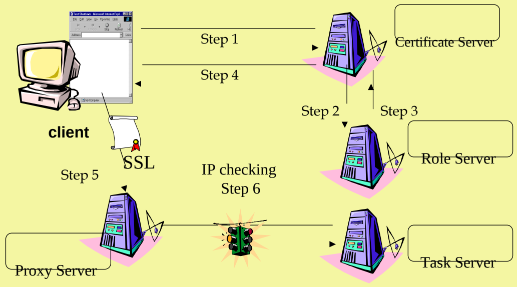
task.html

http://a.com/task.html

task.html

http://b.com/task.html

FINAL SCENARIO



Step 1

Step 4

Certificate Server

Step 2

Step 3

client

SSL

Role Server

Step 5

IP checking
Step 6

Proxy Server

Task Server