**INFS 767 Fall 2001**

**RBAC Architectures and Mechanisms**

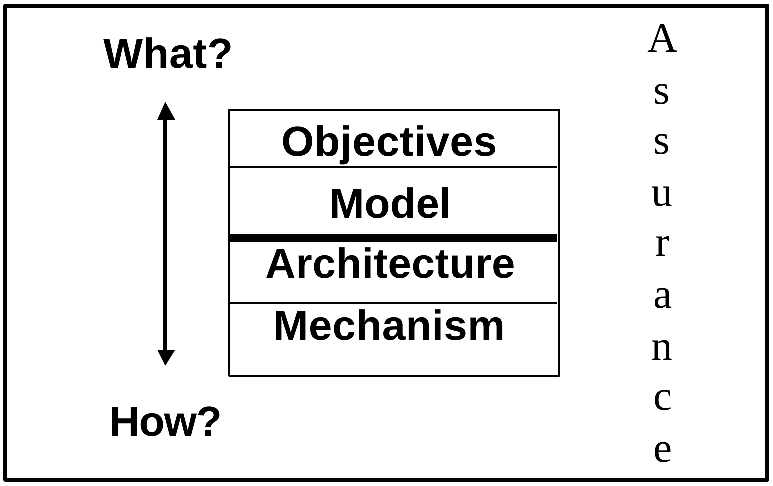
**Prof. Ravi Sandhu**

# AUTHORIZATION, TRUST AND RISK

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

  **so as to manage risk**

# THE OM-AM WAY







# LAYERS AND LAYERS

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

# OM-AM AND MANDATORY ACCESS CONTROL (MAC)

**What?**

| |
|---|
| **No information leakage** |
| **Lattices (Bell-LaPadula)** |
| **Security kernel** |
| **Security labels** |

**How?**

Assurance





# OM-AM AND DISCRETIONARY ACCESS CONTROL (DAC)

**What?**

| |
|---|
| **Owner-based discretion** |
| **numerous** |
| **numerous** |
| **ACLs, Capabilities, etc** |

**How?**

Assurance

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

**What?**

| |
|---|
| **Objective neutral** |
| **RBAC96, ARBAC97, etc.** |
| **user-pull, server-pull, etc.** |
| **certificates, tickets, PACs, etc.** |

**How?**

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# 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**

# DISTRIBUTED RBAC (DRBAC) CASE STUDY

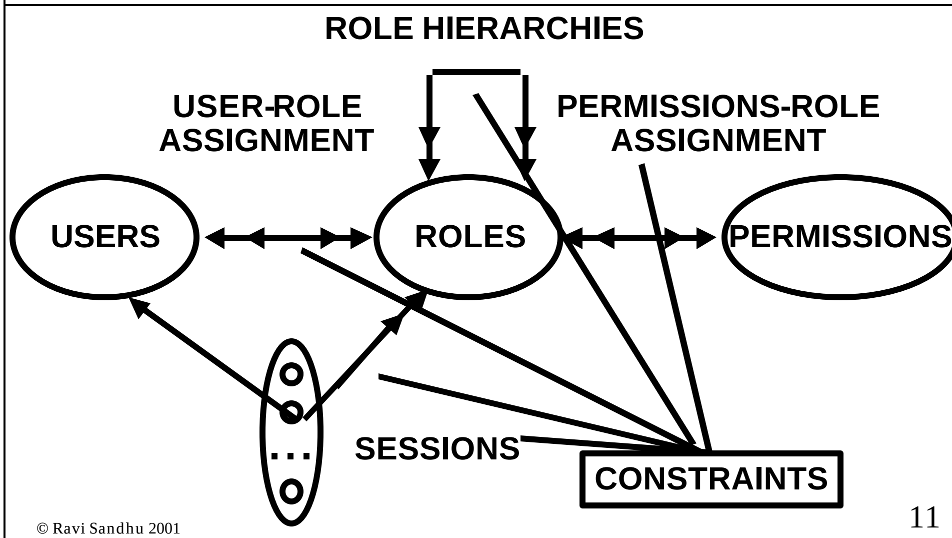
- **Permission-role assignment**
  - **Locally determined at each simulation model**
- **User-role assignment**
  - **A user can be assigned to a role if and only if <u>all</u> simulation models using that role agree**
  - **A user is revoked from a role if and only if <u>any</u> simulation model using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




# 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!**

# RBAC3






# 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

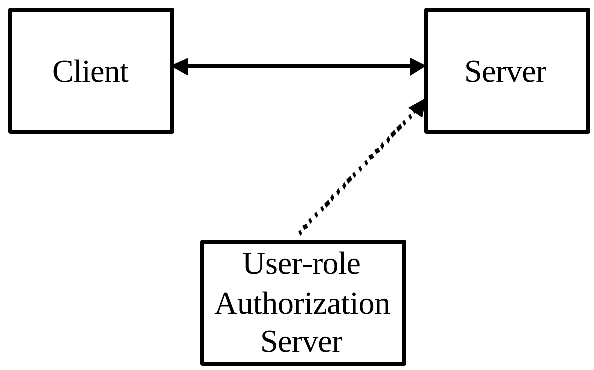
- **Can formalize the administrative rules given earlier**
- **For each simulation model designate a unique user to be the chief security administrator who is authorized to assign and revoke users from the security administrator role for that model**




# 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**

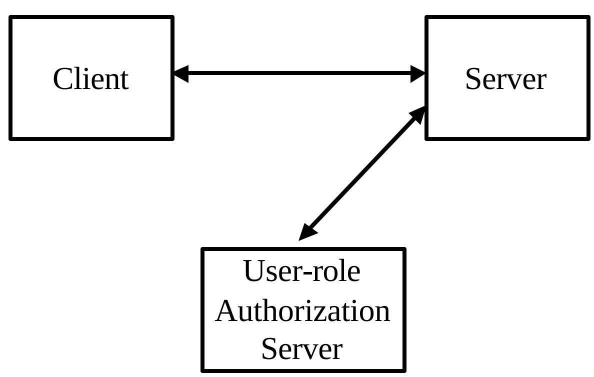
# SERVER MIRROR



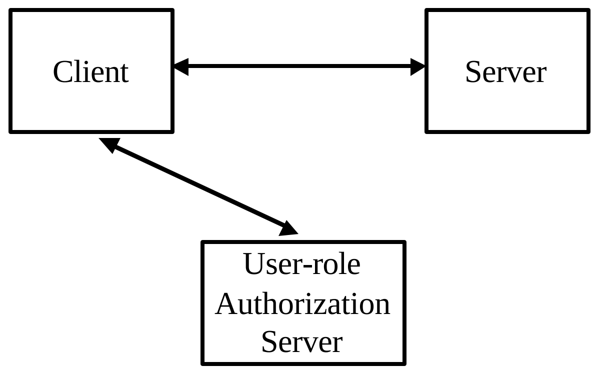




# SERVER-PULL



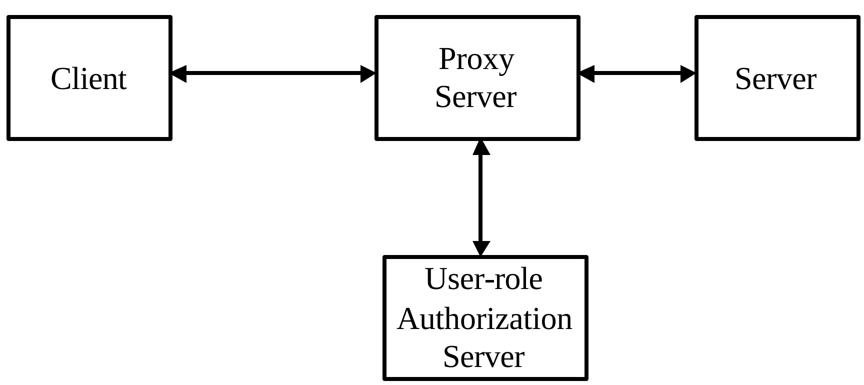
# USER-PULL



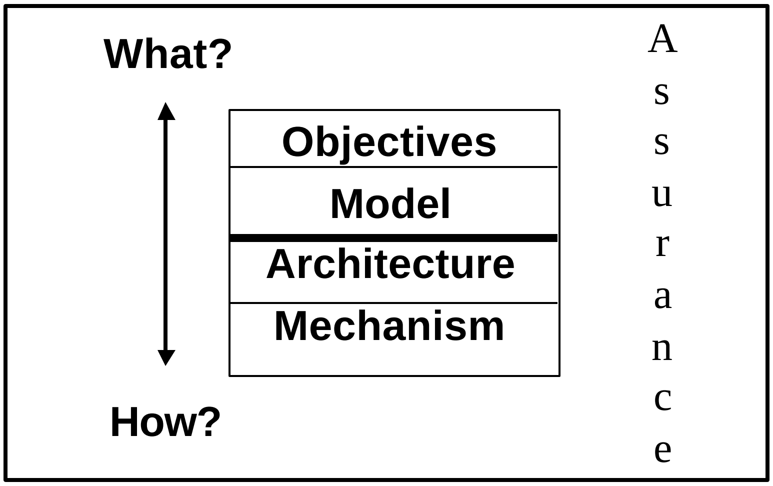




# PROXY-BASED



# THE OM-AM WAY







# Secure Attribute Services on the Web

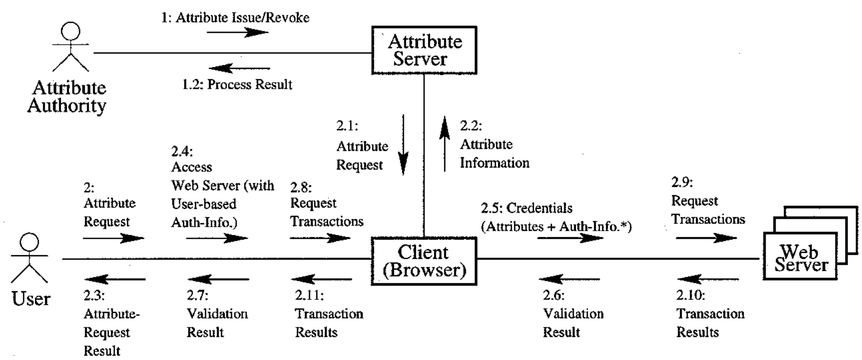
- **WWW (World Wide Web)**
  - **widely used for electronic commerce and business**
  - **supports synthesis of technologies**
  - **mostly, Web servers use identity-based access control**
    - **scalability problem**

# 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



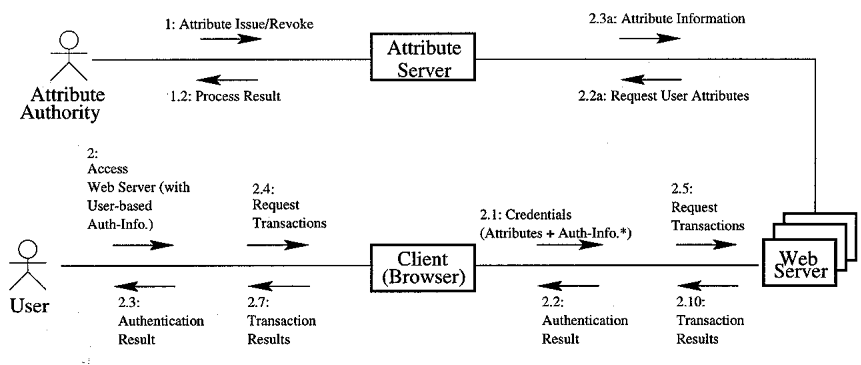

*Authentication Information can be either user-based or host-based.

# 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



# 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




# 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 |

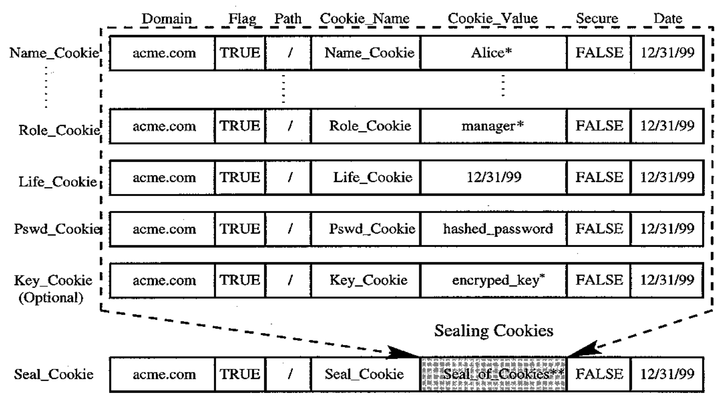
# Security Threats to Cookies

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





# Secure Cookies on the Web

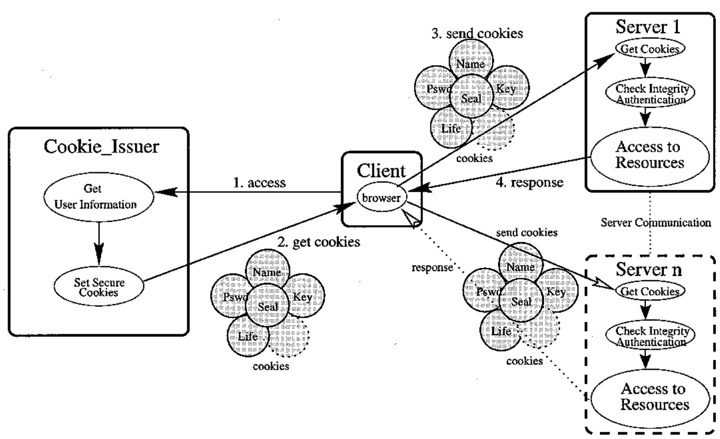



* Sensitive fields can be encrypted in the cookies.
** Seal of Cookies can be either MAC or signed message digest of cookies.
Note: Pswd_Cookie can be replaced with one of the other authentication cookies in Figure 4.1

# A Set of Secure Cookies




# 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




# Authentication Cookies

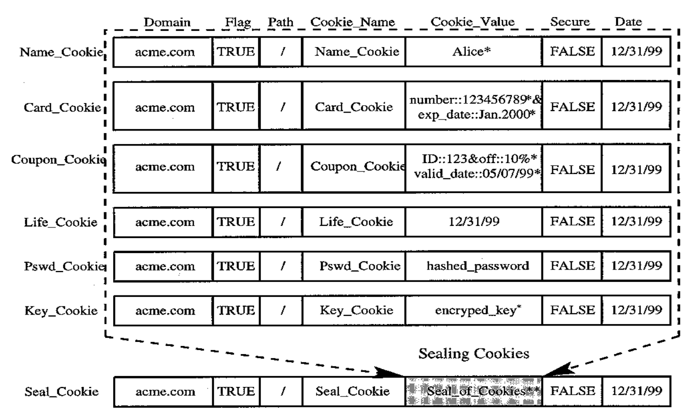
| | Domain | Flag | Path | Cookie_Name | Cookie_Value | Secure | Date |
|---|---|---|---|---|---|---|---|
| IP_Cookie | acme.com | TRUE | / | IP_Cookie | 129.174.100.88 | FALSE | 12/31/99 |
| Pswd_Cookie | acme.com | TRUE | / | Pswd_Cookie | hashed_password | FALSE | 12/31/99 |
| KT_Cookie | acme.com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

# 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**

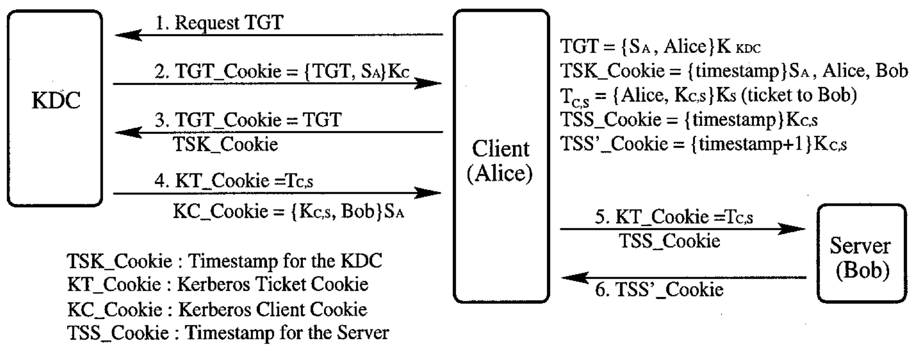


# Secure Cookies for Electronic Transactions




* 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

# Kerberos-Based Authentication by Secure Cookies






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

Sealing Cookies

* 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 |

Cookie_Issuer Signs on the Cookies

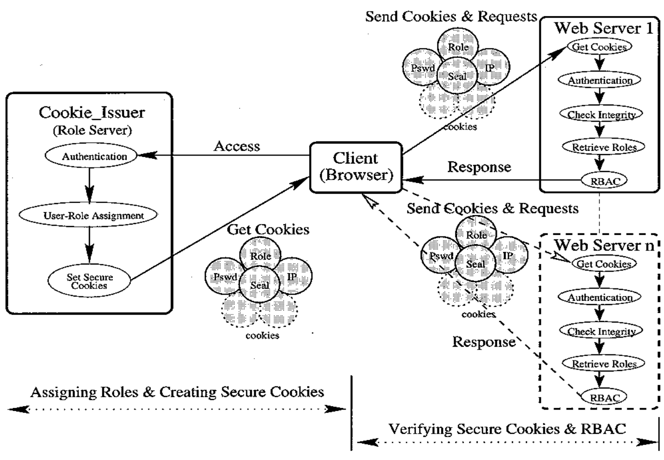
| | Domain | Flag | Path | Cookie_Name | Cookie_Value | Secure | Date |
|---|---|---|---|---|---|---|---|
| Seal_Cookie | acme.com | TRUE | / | Seal_Cookie | Digital_Signature | FALSE | 12/31/99 |

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





# RBAC on the Web by Secure Cookies



# 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)**





# 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
```

# Smart Certificates

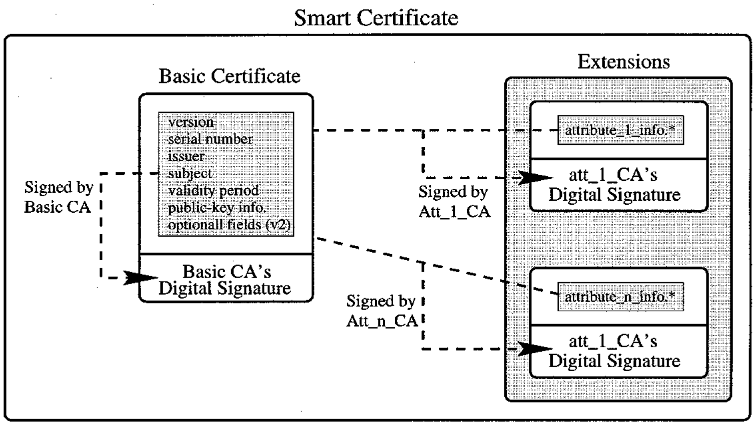
- ❖ **Short-Lived Lifetime**
  - ➢ **More secure**
    - **typical validity period for X.509 is months (years)**
    - **users may leave copies of the corresponding keys behind**
    - **the longer-lived certificates have a higher probability of being attacked**
  - ➢ **No Certificate Revocation List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




# 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.





# 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.

# 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: hEwDNMBB1eJQrWEBAgCS8TzT2/NMvn/xrkRsq/fRMSV3k1UTEYkZoI
            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
```



# 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**

# 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**

## 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

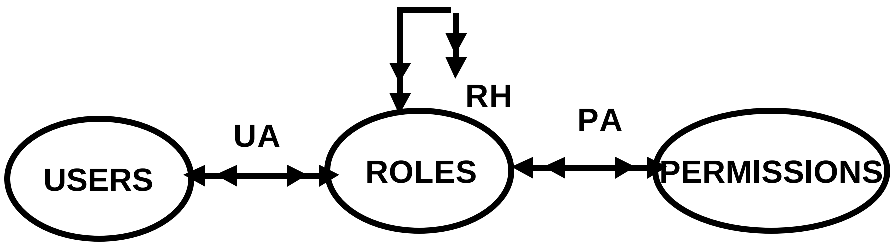
- **Inject role-based access control (RBAC) into an existing web-based workflow system**




# 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**

# SIMPLIFIED RBAC MODEL

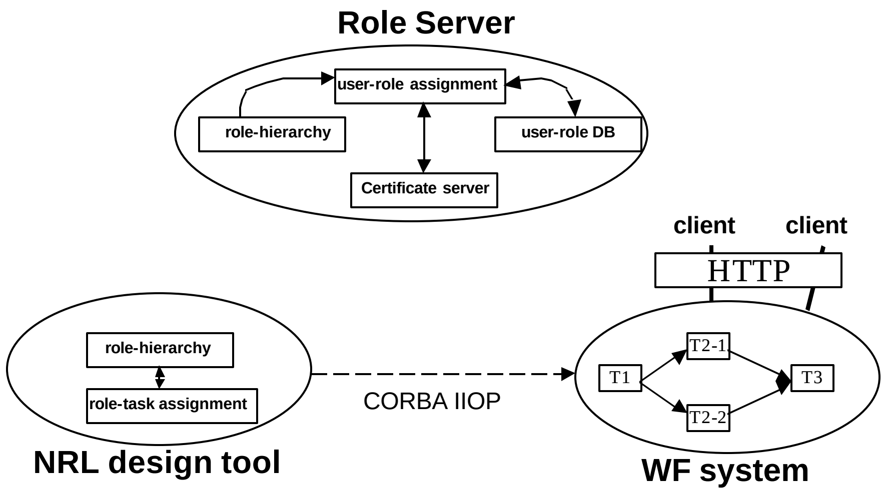





# ROLE-BASED SECURE WORKFLOW SYSTEM

- **Workflow Design Tool**
- **Workflow (WF) System**
- **Role Server**

# BASIC COMPONENTS



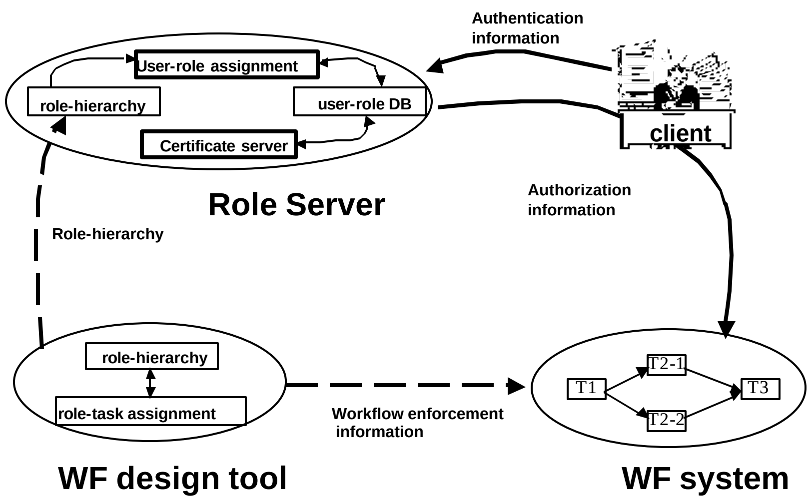




# ARCHITECTURES

- **USER-PULL STYLE**
- **SERVER-PULL STYLE**

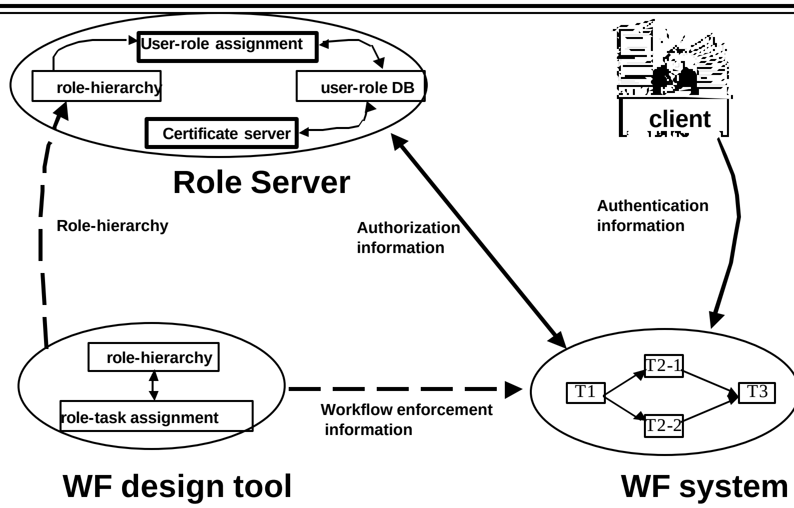
# USER-PULL STYLE







# SERVER-PULL STYLE

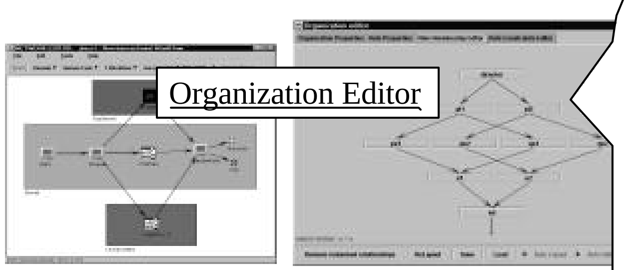


# NRL (Naval Research Lab.) DESIGN TOOL

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



# NRL DESIGN TOOL (Cont'd)




Platform: Windows NT, JDK1.2

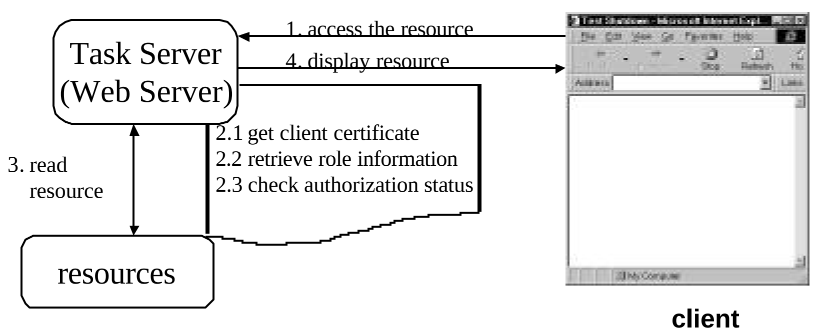

```
<?xml version="1.0"?>
<!--URA    Revision: 1
   Mon Dec 07 15:59:28 EDT 1999 -->
<!DOCTYPE Organization SYSTEM
   "../dtd/Organization.dtd">
<Organization id="Organization_URA">
<Name>URA</Name>
<Description></Description>
<Role id="director">
<Name>director</Name>
<Description></Description>
<Privileges>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



# ROLE SERVER

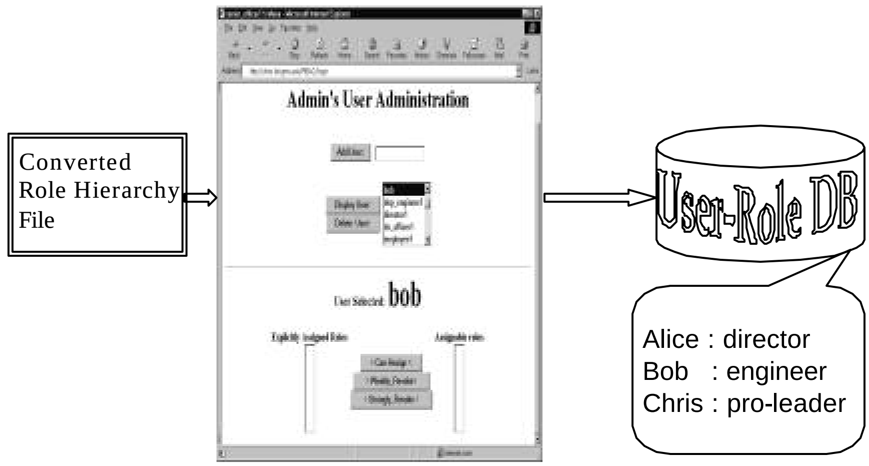
- User Role Assignment
- Certificate Server




# USER ROLE ASSIGNMENT

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

# USER ROLE ASSIGNMENT (Cont'd)



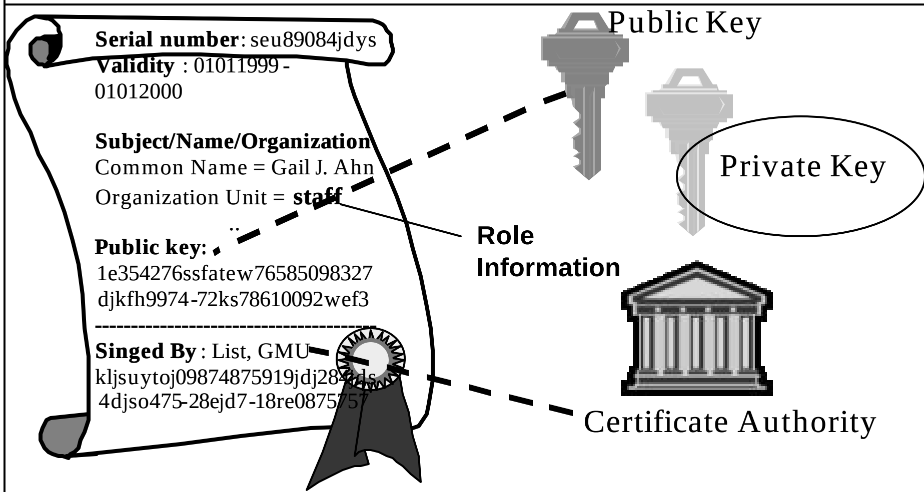





# CERTIFICATE SERVER

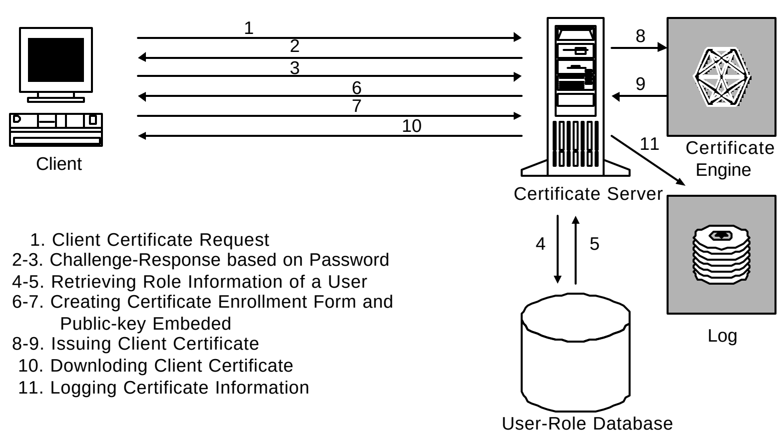
- **authenticate client**
- **retrieve client's role information from user-role database**
- **issue certificate with client's role information**

# X.509 CERTIFICATE



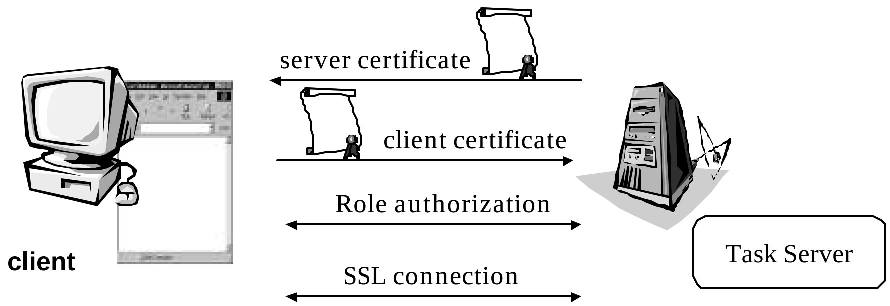



# CERTIFICATE ISSUE




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

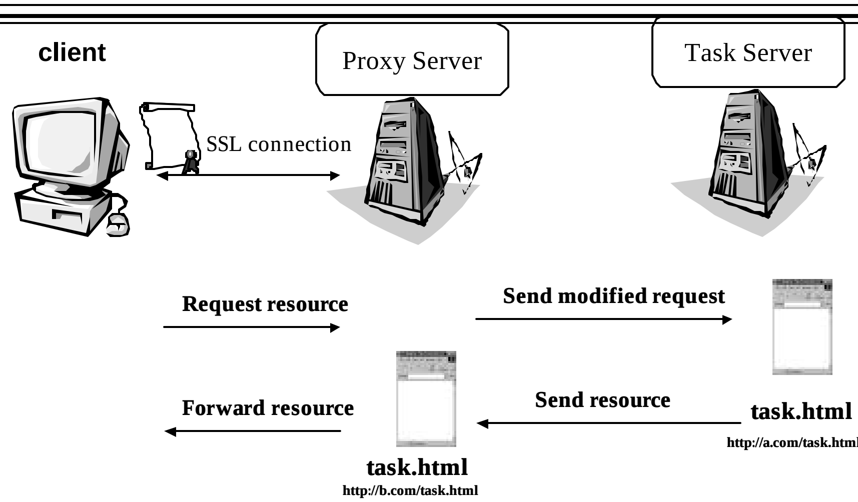
# CERTIFICATE AUTHORIZATION OVER SSL







# REVERSE PROXYING
## (MINIMAL CHANGES IN SERVER SIDE)



# FINAL SCENARIO