The Anatomy of a Secure Java Web App Using Apache Fortress

October 11, 2018

AppSec USA, San Jose

Objective

Think about how we should be securing web apps.

(If we removed all stops)

Intro

- John Tumminaro
  - VP Technology, GlobalLogic
- Shawn McKinney
  - Software Architect, Symas

Agenda

1. Have a look at Equifax
2. End-to-End Security w/ Apache Fortress Samples
3. Talk about RBAC and ABAC

Recommendation

Listen and absorb *conceptually*. Slides are published and have the *details*.

https://iamfortress.files.wordpress.com/2018/09/anatomy-secure-web-app-appsec-2018-v41.pdf

What's The Problem

- Equifax Breach
  - 143 million Americans' personal info, including names, addresses, dates of birth and SSNs compromised.
  - Only a veneer of security in place.

https://cwiki.apache.org/confluence/display/WW/S2-045

Summary

Possible Remote Code Execution when performing file upload based on Jakarta Multipart parser.

Who should read this	All Struts 2 developers and users
Impact of vulnerability	Possible RCE when performing file upload based on Jakarta Multipart parser
Maximum security rating	Critical
Recommendation	Upgrade to Struts 2.3.32 or Struts 2.5.10.1
Affected Software	Struts 2.3.5 - Struts 2.3.31, Struts 2.5 - Struts 2.5.10
Reporter	Nike Zheng <nike dot zheng at dbappsecurity dot com dot cn>
CVE Identifier	CVE-2017-5638

The Exploit

"The Jakarta Multipart parser in Apache Struts 2 2.3.x before 2.3.32 and 2.5.x before 2.5.10.1 mishandles file upload, which allows remote attackers to execute arbitrary commands via a #cmd= string in a crafted Content-Type HTTP header, as exploited in the wild in March 2017."

https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2017-5638

The Exploit

CVE-2017-5638: Apache Struts 2 Vulnerability Leads to Remote Code Execution

Posted on: March 9, 2017 at 5:51 am **Posted in:** Exploits, Vulnerabilities
Author: Suraj Sahu (Vulnerability Research Engineer)

Apache Struts is a free and open-source framework used to build Java web applications. We looked into past several Remote Code Execution (RCE) vulnerabilities reported in Apache Struts, and observed that in most of them, attackers have used Object Graph Navigation Language (OGNL) expressions. The use of OGNL makes it easy to execute arbitrary code remotely because Apache Struts uses it for most of its processes.

Using OGNL, a researcher found a new remote code execution vulnerability in Apache Struts 2, designated as CVE-2017-5638. An exploit has been reported to be already in the wild; our own research and monitoring have also seen attacks using the vulnerability.

https://blog.trendmicro.com/trendlabs-security-intelligence/cve-2017-5638-apache-struts-vulnerability-remote-code-execution/

OGNL, again

Apache Struts RCE payloads often come in the form of Object-Graph Navigation Library (OGNL) expressions. OGNL is a language for interacting with the properties and functions of Java classes and Apache Struts supports it in many contexts.

For example, the snippet below uses OGNL to dynamically insert the value "5" into a webpage by calling a function.

```
<s:property value="%{getSum(2,3)}" />
```

OGNL expressions can also be used for more general code execution:

```
${
    #_memberAccess["allowStaticMethodAccess"]=true,
   @java.lang.Runtime@getRuntime().exec('calc')
}
```

https://blog.cloudflare.com/apache-struts-s2-057/

Behind The Equifax Breach

https://www.brighttalk.com/webcast/13983/280311/behind-the-equifax-breach-a-deep-dive-into-apache-struts-cve-2017-5638

SATURDAY SEPTEMBER 09, 2017

Apache Struts Statement on Equifax Security Breach

UPDATE: MEDIA ALERT: The Apache Software Foundation Confirms Equifax Data Breach Due to Failure to Install Patches Provided for Apache® Struts™ Exploit

2. Establish a process to quickly roll out a security fix release of your software product once supporting frameworks or libraries needs to be updated for security reasons. Best is to think in terms of hours or a few days, not weeks or months. Most breaches we become aware of are caused by failure to update software components that are known to be vulnerable for months or even years.

Once followed, these recommendations help to prevent breaches such as unfortunately experienced by Equifax.

For the Apache Struts Project Management Committee,

René Gielen
Vice President, Apache Struts

https://blogs.apache.org/foundation/entry/apache-struts-statement-on-equifax

The Solution

Ensure all appropriate patches have been applied.

https://www.owasp.org/index.php/OWASP_Dependency_Check

OWASP Dependency-Check

https://www.owasp.org/index.php/OWASP_Dependency_Check

OWASP Dependency-Check

Dependency-Check is a utility that identifies project dependencies and checks if there are any known, publicly disclosed, vulnerabilities. Currently, Java and .NET are supported; additional experimental support has been added for Ruby, Node.js, Python, and limited support for C/C++ build systems (autoconf and cmake). The tool can be part of a solution to the OWASP Top 10 2017 A9:2017-Using Components with Known Vulnerabilities [1] previously known as OWASP Top 10 2013 A9 - Using Components with Known Vulnerabilities.

Quick Download

Version 3.3.2

- Command Line
- Ant Task
- Maven Plugin
- Gradle Plugin
- Jenkins Plugin
- Mac Homebrew

OWASP Vulnerability Scanning (Java)

Add to your Maven pom.xml file:

```
<plugin>
        <groupId>org.owasp</groupId>
        <artifactId>dependency-check-maven</artifactId>
        <version>3.3.1</version>
        <configuration>
        <failBuildOnAnyVulnerability>true</failBuildOnAnyVulnerability>

    <suppressionFile>${project.basedir}…/suppression.xml</suppressionFile>
        </configuration>
</plugin>
```

Apache Struts Statement on Equifax Security Breach

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3. Any complex software contains flaws. Don't build your security policy on the assumption that supporting software products are flawless, especially in terms of security vulnerabilities.

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How do we make our software free of *unknown* vulnerabilities?

The Solution (Take 2)

Practice the principle of least privilege.

(Employ mandatory access controls)

Employ a Runtime Java Security Policy

```
grant codeBase "file:${catalina.home}/webapps/my-web-app-1/-" {
    permission java.net.SocketPermission "localhost", "resolve";
    permission java.net.SocketPermission "127.0.0.1:32768", "connect,resolve";
    permission java.lang.reflect.ReflectPermission "suppressAccessChecks";
    permission java.io.SerializablePermission "enableSubclassImplementation";
    permission java.io.FilePermission "…/resources/", "execute";
    …
    };
```

^ use w/ caution

Example #1

https://github.com/shawnmckinney/remote-code-execution-sample

remote-code-execution-sample

Example shows how to use the Java Security Manager to prevent remote code execution exploits.

Intro to the Problem

- The Problem: Equifax Breach, 143 million Americans' personal info, including names, addresses, dates of birth and SSNs compromised.
- Only a veneer of security was in place.

The Exploit

- The vulnerability *Apache Struts, CVE-2017-5638.*
- http://www.zdnet.com/article/equifax-confirms-apache-struts-flaw-it-failed-to-patch-was-to-blame-for-data-breach/

The Exploit

CVE-2017-5638: Apache Struts 2 Vulnerability Leads to Remote Code Execution

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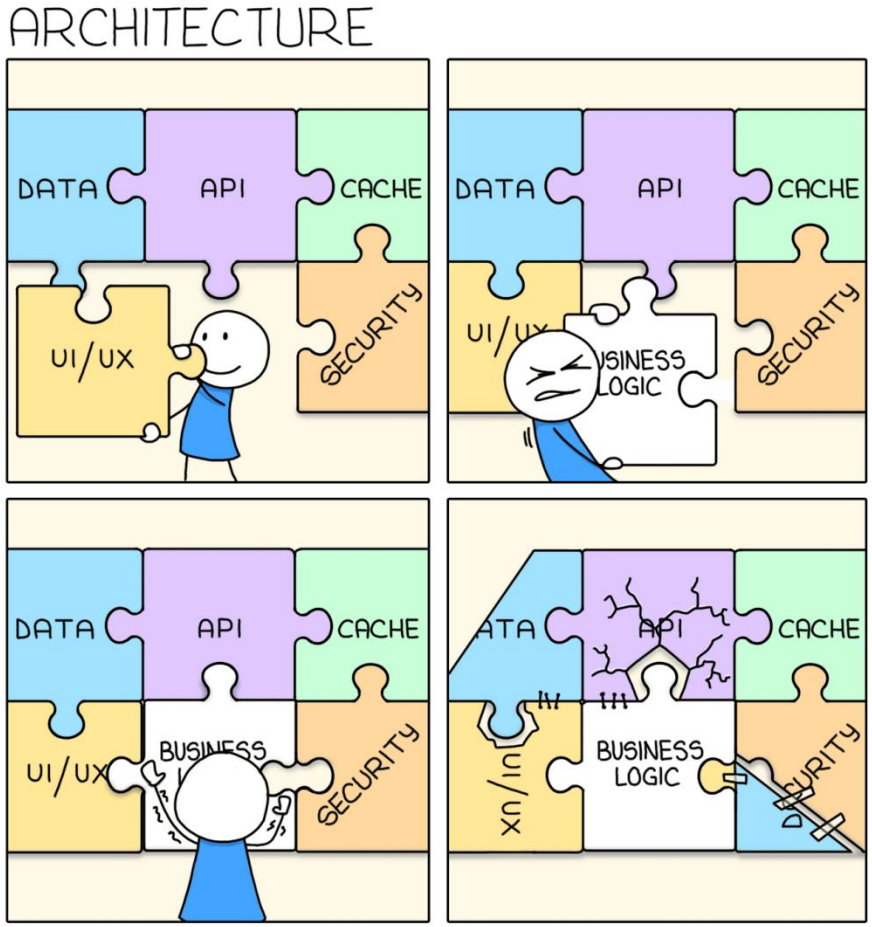
Using OGNL, a researcher found a new remote code execution vulnerability in Apache Struts 2, designated as CVE-2017-5638. An exploit has been reported to be already in the wild; our own research and monitoring have also seen attacks using the vulnerability.

Not a Perfect Solution

```
grant codeBase "file:${catalina.home}/webapps/my-web-app-1/-" {
   permission java.net.SocketPermission "localhost", "resolve";
   permission java.io.FilePermission "…/resources/good-scripts*", "execute";
   permission java.net.SocketPermission "127.0.0.1:32768", "connect,resolve";
   permission java.lang.reflect.ReflectPermission "suppressAccessChecks";
   permission java.io.SerializablePermission "enableSubclassImplementation";
   permission java.lang.reflect.ReflectPermission "suppressAccessChecks";
   };
```

Permission Target Name	What the Permission Allows	Risks of Allowing this Permission
suppressAccessChecks	ability to access fields and invoke methods in a class. Note that this includes not only public, but protected and private fields and methods as well.	This is dangerous in that information (possibly confidential) and methods normally unavailable would be accessible to malicious code.

What now?



https://www.monkeyuser.com/2018/architecture/

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Apache Struts Statement on Equifax Security Breach

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The Apache Struts Project Management Committee (PMC) would like to comment on the Equifax security breach, its relation to the Apache Struts Web Framework and associated media coverage.

4. Establish security layers. It is good software engineering practice to have individually secured layers behind a public-facing presentation layer such as the Apache Struts framework. A breach into the presentation layer should never empower access to significant or even all back-end information resources.

Once followed, these recommendations help to prevent breaches such as unfortunately experienced by Equifax.

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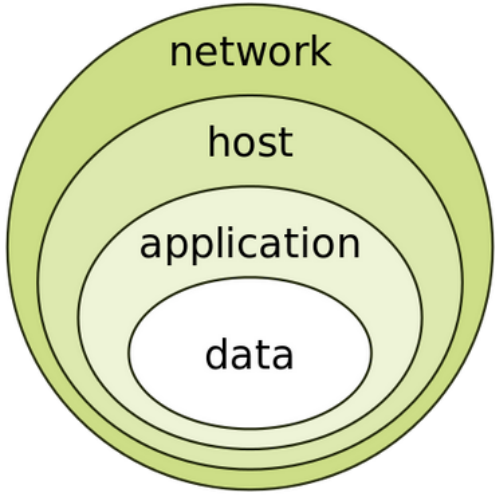
https://blogs.apache.org/foundation/entry/apache-struts-statement-on-equifax

Defense in depth [edit]

https://en.wikipedia.org/wiki/Information_security

Main article: Defense in depth (computing)

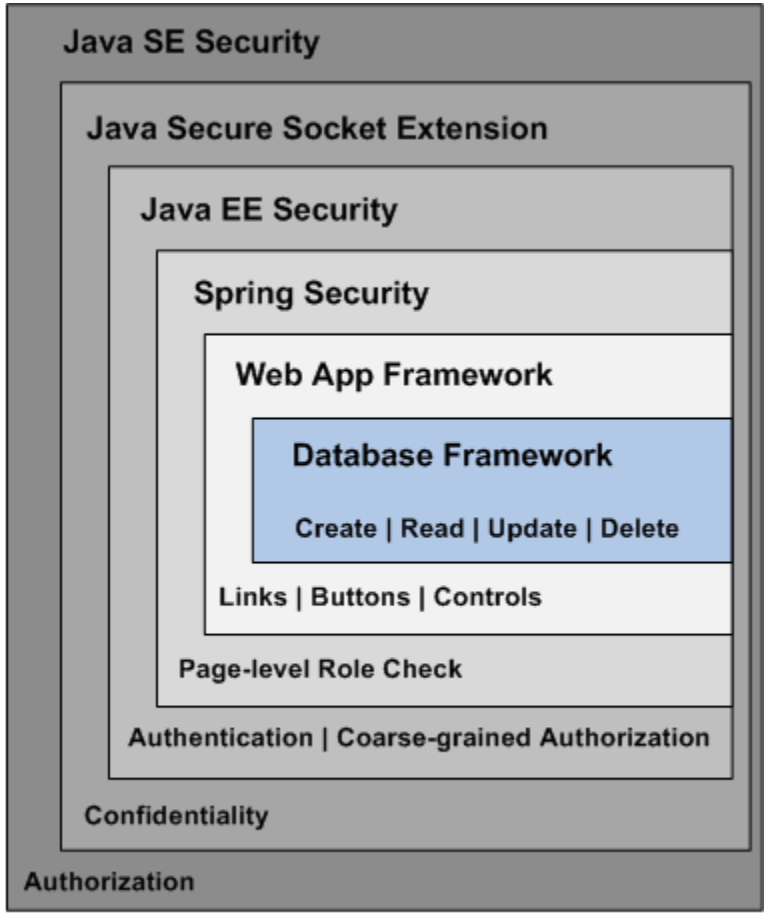
Information security must protect information throughout the life span of the information, from the initial creation of the information on through to the final disposal of the information. The information must be protected while in motion and while at rest. During its lifetime, information may pass through many different information processing systems and through many different parts of information processing systems. There are many different ways the information and information systems can be threatened. To fully protect the information during its lifetime, each component of the information processing system must have its own protection mechanisms. The building up, layering on and overlapping of security measures is called **defense in depth**. In contrast to a metal chain, which is famously only as strong as its weakest link, the defense-in-depth aims at a structure where, should one defensive measure fail, other measures will continue to provide protection.



The onion model of defense in depth

Java Web Security Layers

1. Java SE Security
2. Java Secure Socket Extension (JSSE)
3. Java EE Security
4. Spring Security
5. Web App Framework
6. Database Framework



Each with a specific purpose

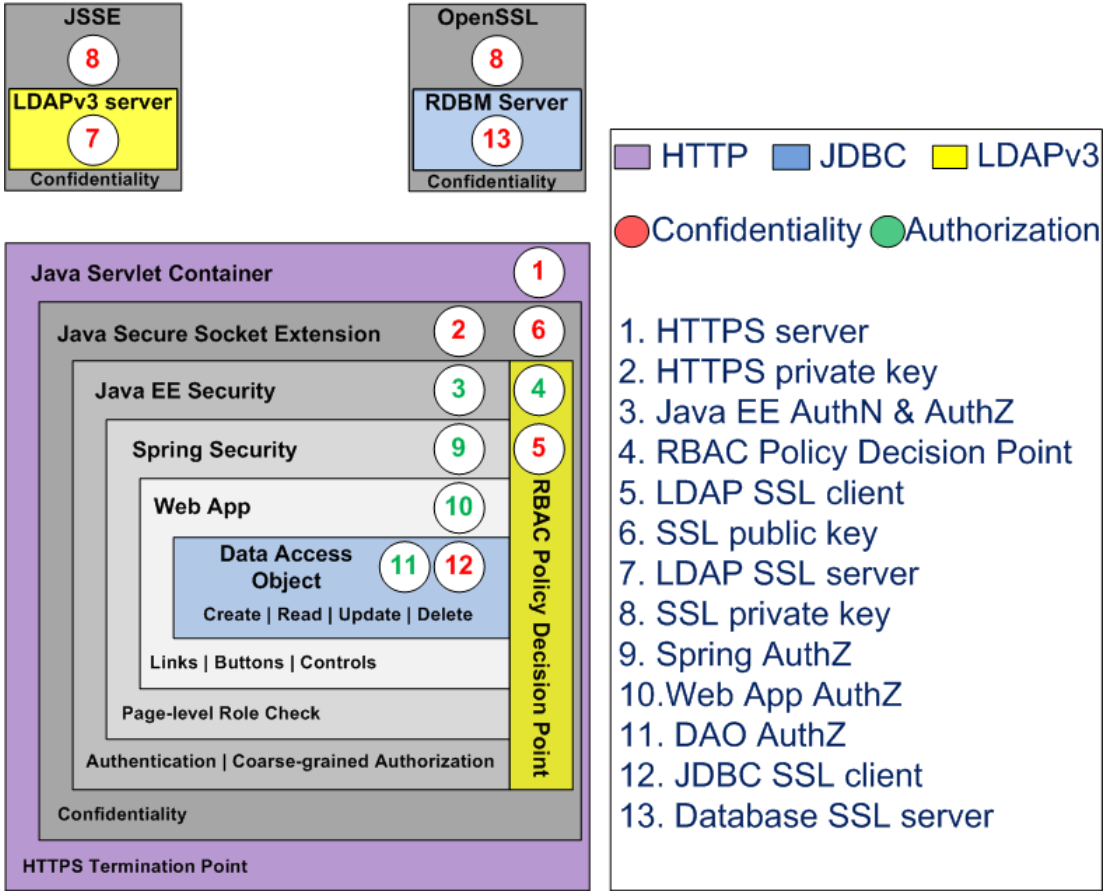
1. Java SE Security ---------- principle of least privilege
2. JSSE ---------- private conversations
3. Java EE Security ---------- deadbolt on front door
4. Spring Security ---------- locks on room doors
5. Web App Framework - locks on equipment in rooms
6. Database Functions ---- content filtering

Example #2

Apache

Fortress

Demo



https://github.com/shawnmckinney/apache-fortress-demo

Enable Java EE Security

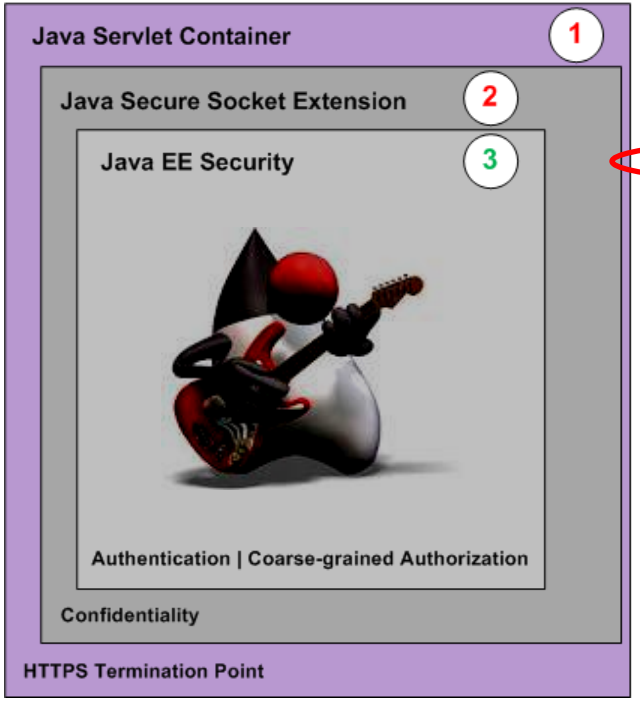
the deadbolt

a. Update web.xml

b. Drop the proxy jar

c. Add context.xml

d. Add fortress to pom.xml



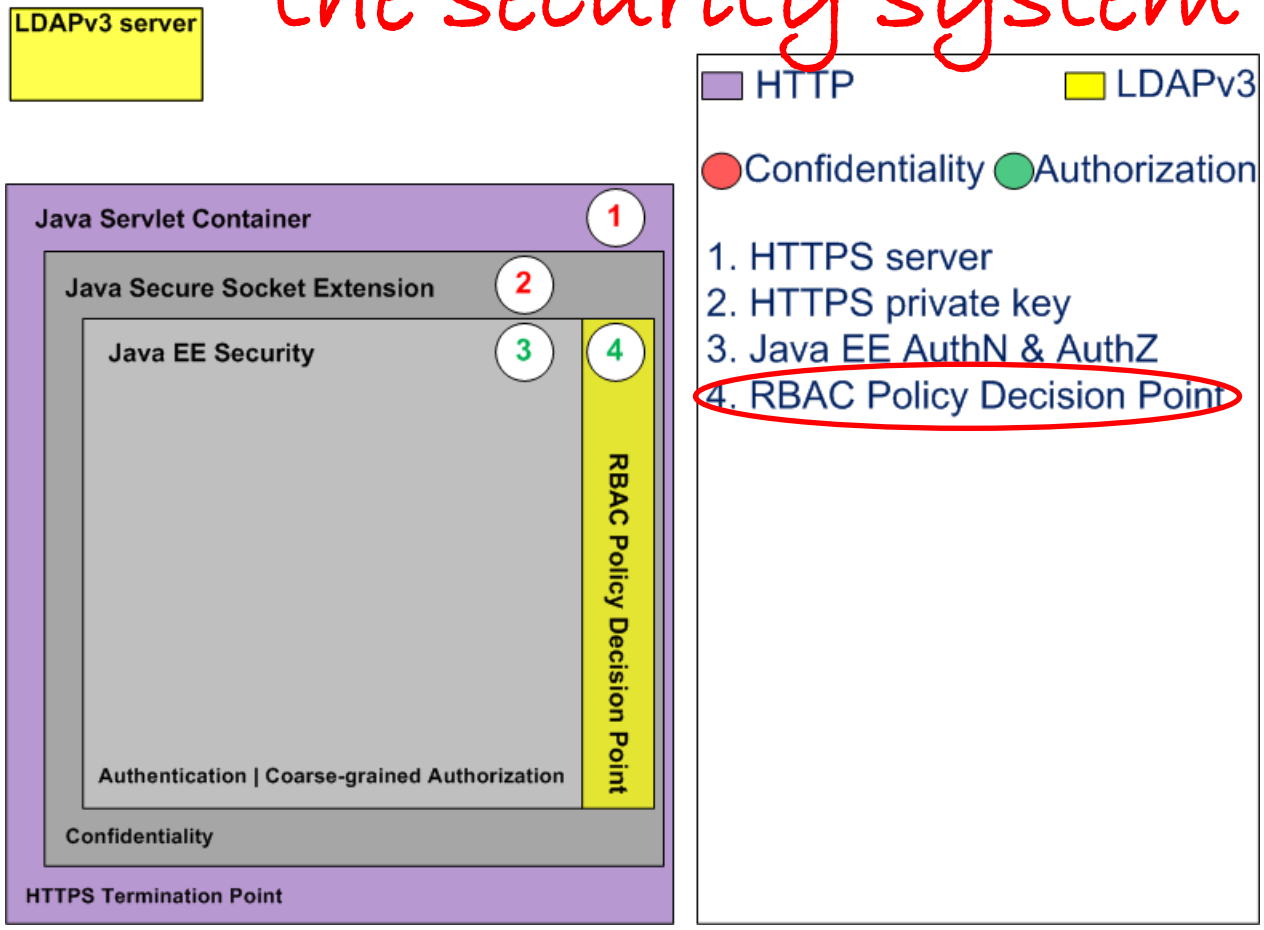
HTTP

Confidentiality Authorization

1. HTTPS server
2. HTTPS private key
3. Java EE AuthN & AuthZ

Setup Policy Decision Point

the security system



Use ANSI RBAC INCITS 359 Specification

RBAC0:

- Users, Roles, Perms, Sessions

RBAC1:

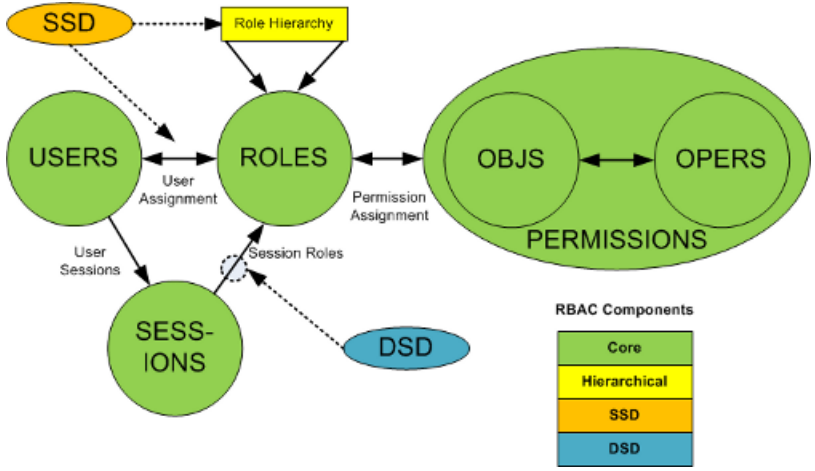
- Hierarchical Roles

RBAC2:

- Static Separation of Duties

RBAC3:

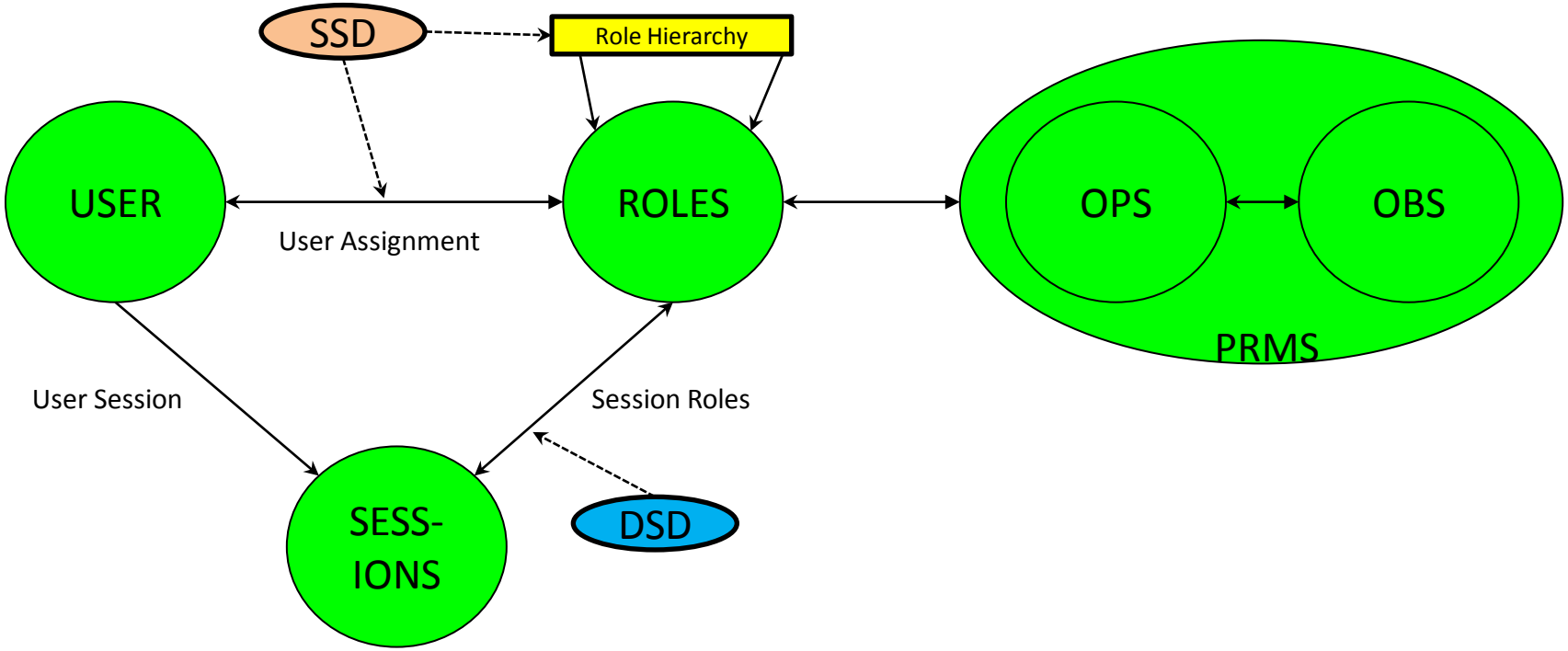
- Dynamic Separation of Duties



The Standards Journey

- An RBAC authority reference:
  - http://csrc.nist.gov/groups/SNS/rbac/
- An original paper on RBAC:
  - http://csrc.nist.gov/groups/SNS/rbac/documents/ferraiolo-kuhn-92.pdf
- An updated paper on RBAC:
  - http://csrc.nist.gov/groups/SNS/rbac/documents/sandhu-ferraiolo-kuhn-00.pdf
- The current standard
  - http://profsandhu.com/journals/tissec/ANSI+INCITS+359-2004.pdf

Use ANSI RBAC INCITS 359 Specification



Use RBAC Object Model

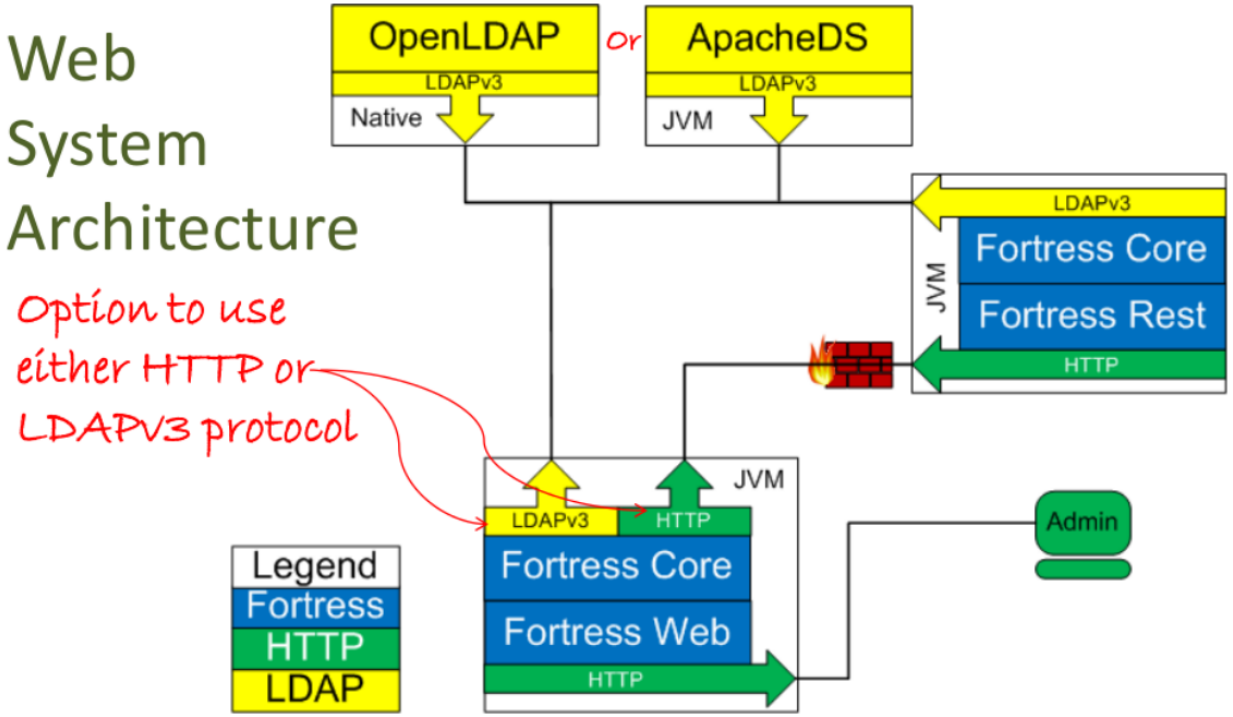
Six basic elements:

1. **User** – human or machine entity
2. **Role** – a job function within an organization
3. **Object** – maps to system resources
4. **Operation** – executable image of program
5. **Permission** – approval to perform an Operation on one or more Objects
6. **Session** – contains set of activated roles for User

Apache Fortress™

Access Management SDK and Web Components

A standards-based access management system, written in Java, supports ANSI INCITS 359 RBAC and more.



Use RBAC Functional Model

APIs form three standard interfaces:

1. Admin – Add, Update, Delete
2. Review – Read, Search
3. System – Access Control

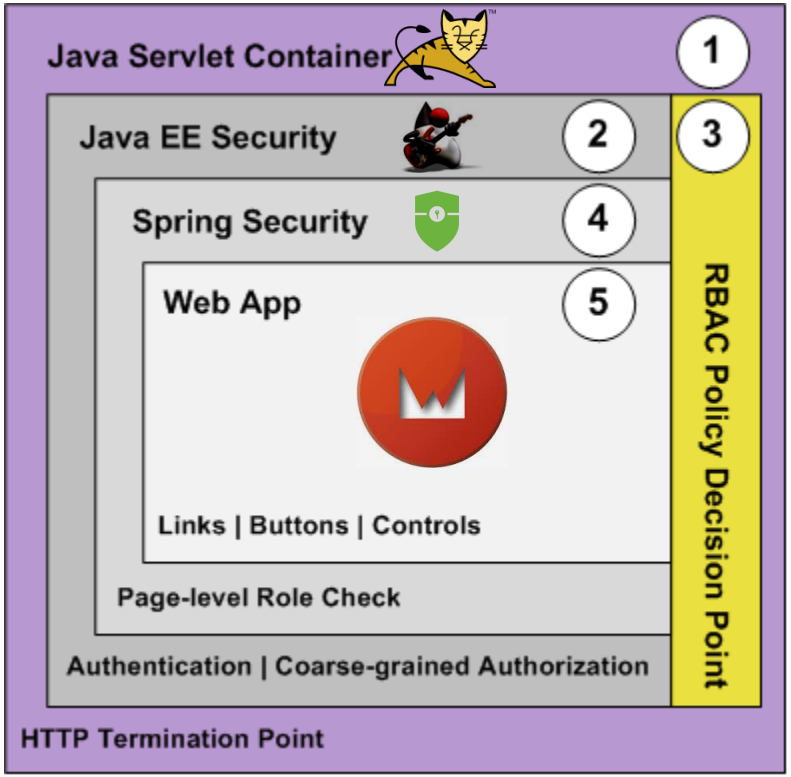
Use RBAC Functional Model

System Manager APIs:

http://directory.apache.org/fortress/gen-docs/latest/apidocs/org/apache/directory/fortress/core/impl/AccessMgrImpl.html

1. createSession – authenticate, activate roles
2. checkAccess – permission check
3. sessionPermissions – all perms active for user
4. sessionRoles – return all roles active
5. addActiveRole – add new role to session
6. dropActiveRole – remove role from session

Example #3 : Role Engineering Sample



https://github.com/shawnmckinney/role-engineering-sample

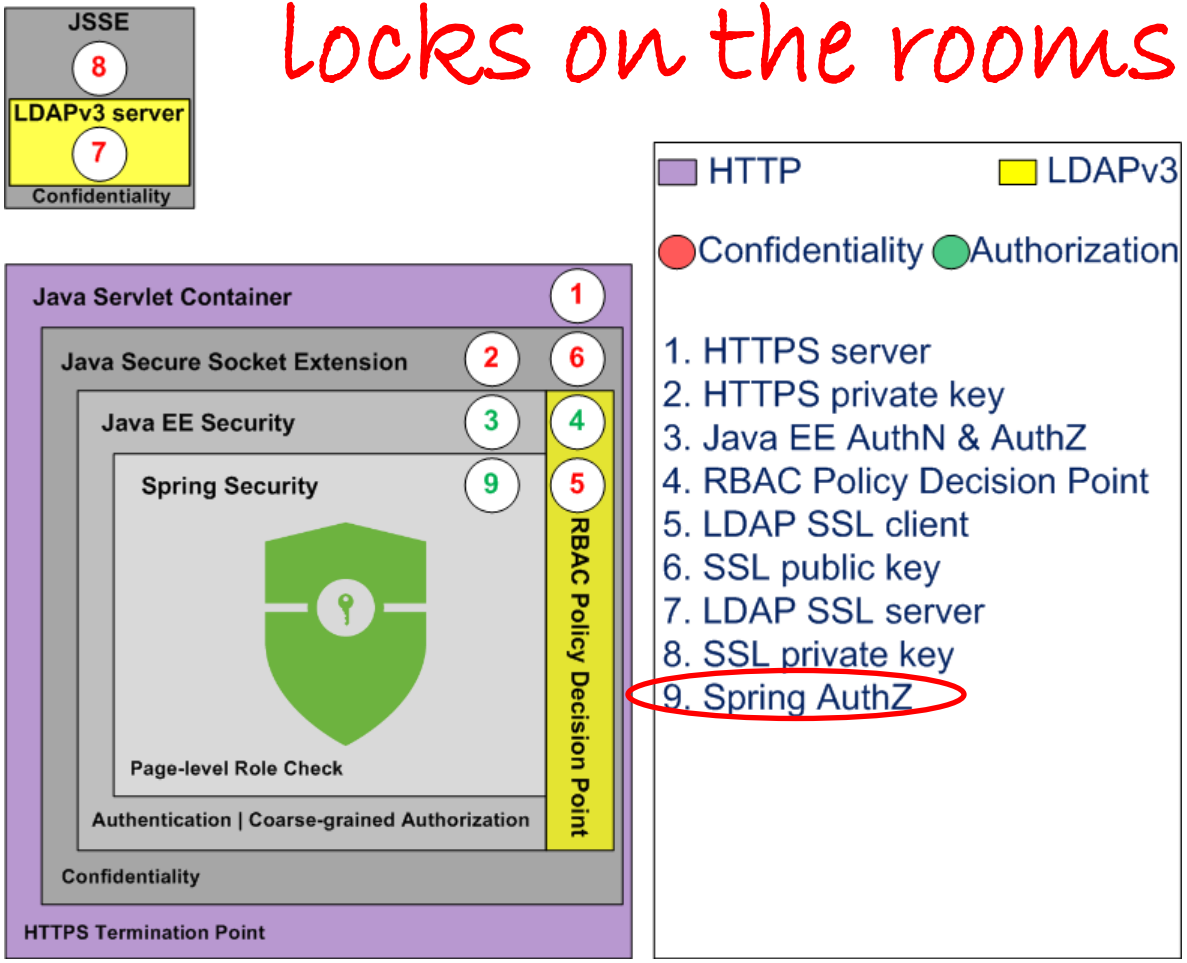
HTTP LDAPv3

1. HTTP server
2. Java EE AuthN & AuthZ
3. RBAC Policy Decision Point
4. Spring AuthZ
5. Web App AuthZ

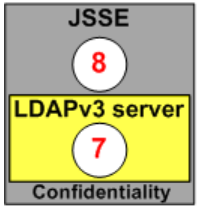
Enable Spring Security

a. Authorization

b. Role mapping



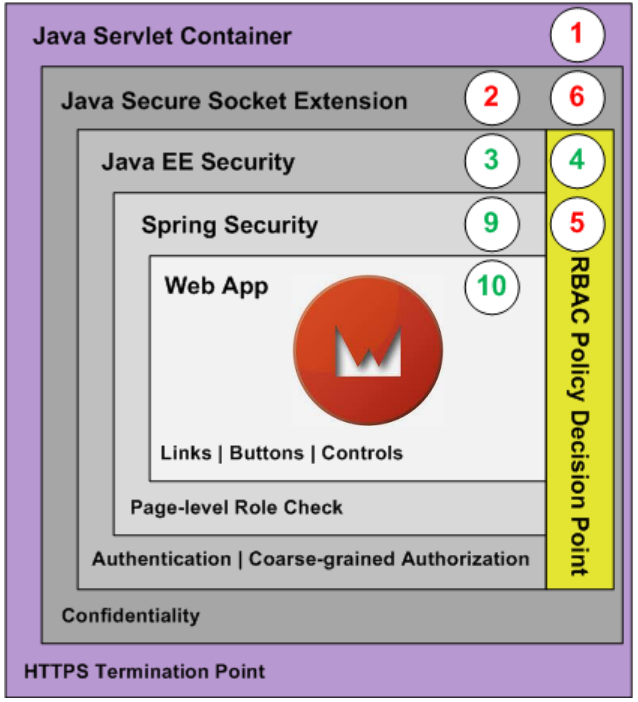
Web App Authorization

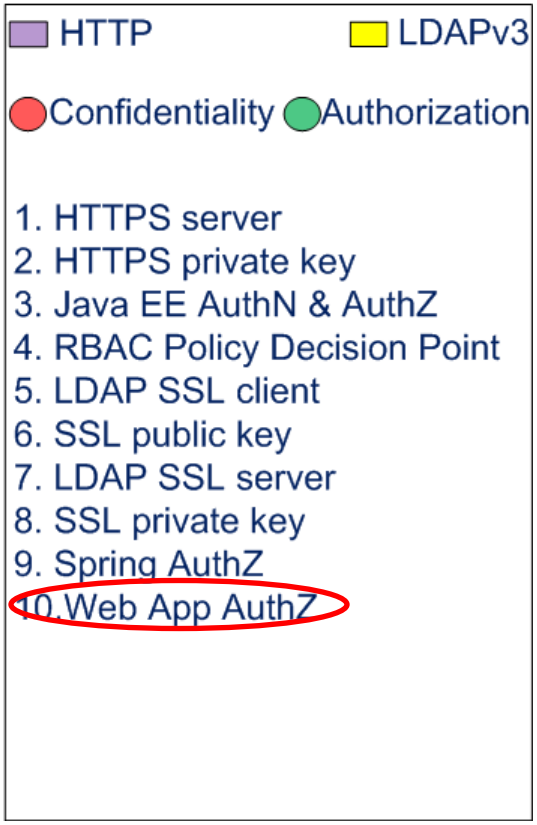


locks on equipment

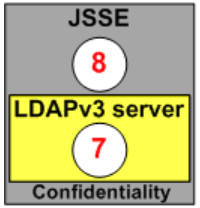
Add fine-grained checks:

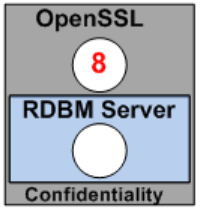
a. Page links
b. Buttons
c. Other controls



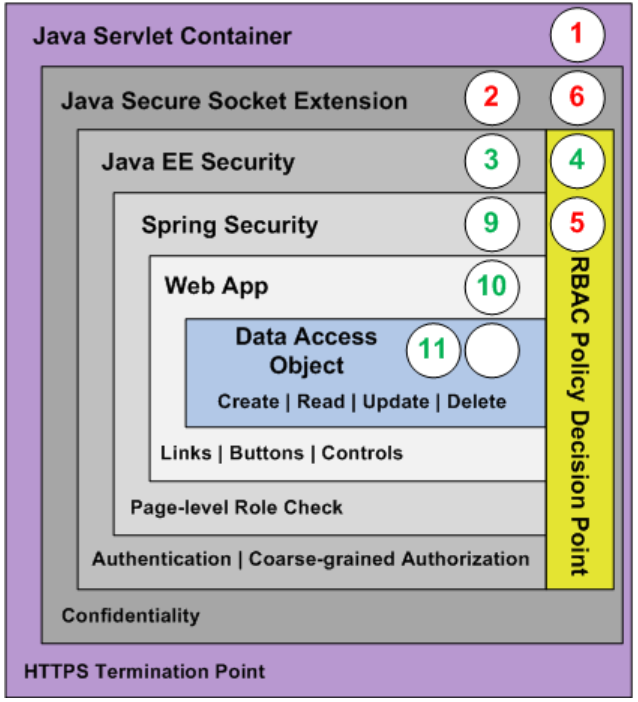


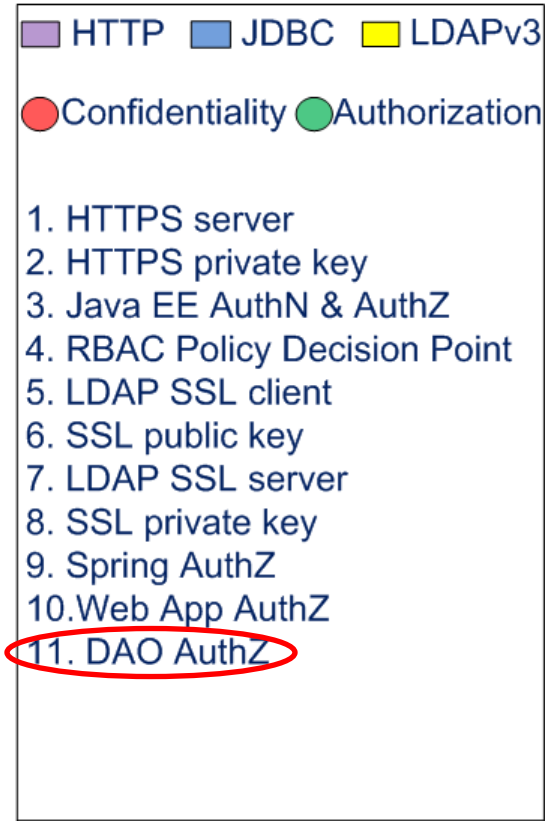
DAO Authorization





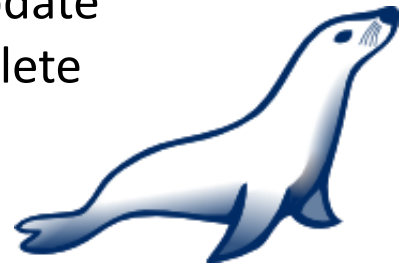
filtering





Add fine-grained Checks to:

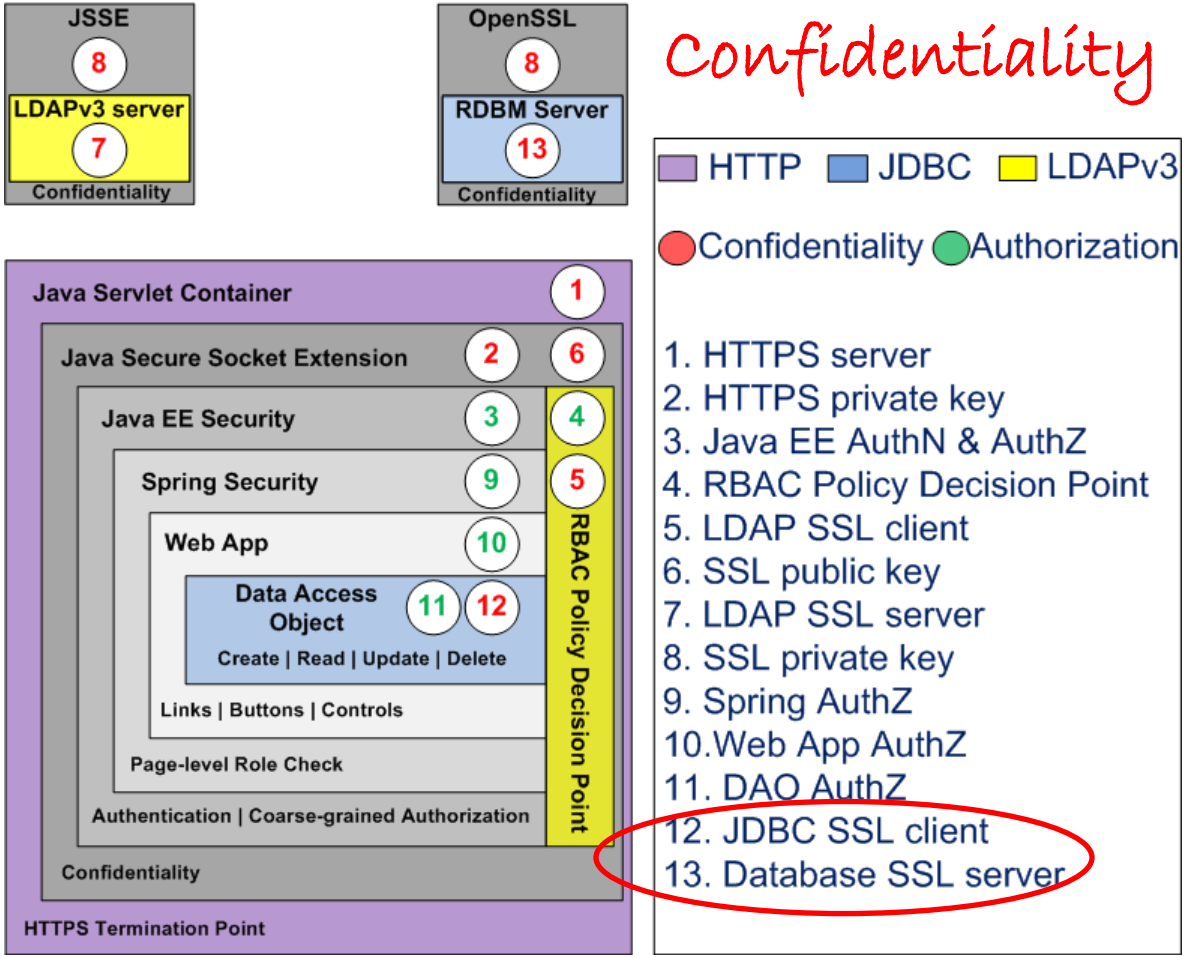
a. Create
b. Read
c. Update
d. Delete



Enable SSL Everywhere

Client
a. public key
b. config

Server
a. private key
b. config



Apache Fortress Demo

- Three Pages and Three Customers
- One role for every page to customer combo
- Users may be assigned to one or more roles
- One and only one role may be activated

Pages	Customer 123	Customer 456	Customer 789
Page One	PAGE1_123	PAGE1_456	PAGE1_789
Page Two	PAGE2_123	PAGE2_456	PAGE2_789
Page Three	PAGE3_123	PAGE3_456	PAGE3_789

User123	Customer 123	Customer 456	Customer 789
Page1	True	False	False
Page2	True	False	False
Page3	True	False	False

User1	Customer 123	Customer 456	Customer 789
Page1	True	True	True
Page2	False	False	False
Page3	False	False	False

User1_123	Customer 123	Customer 456	Customer 789
Page1	True	False	False
Page2	False	False	False
Page3	False	False	False

RBAC Demo


http://www.wright-brothers.org/Information_Desk/Help_with_Homework/Wright_Photos/Wright_Photos_images/1902_Glider_Flying.jpg

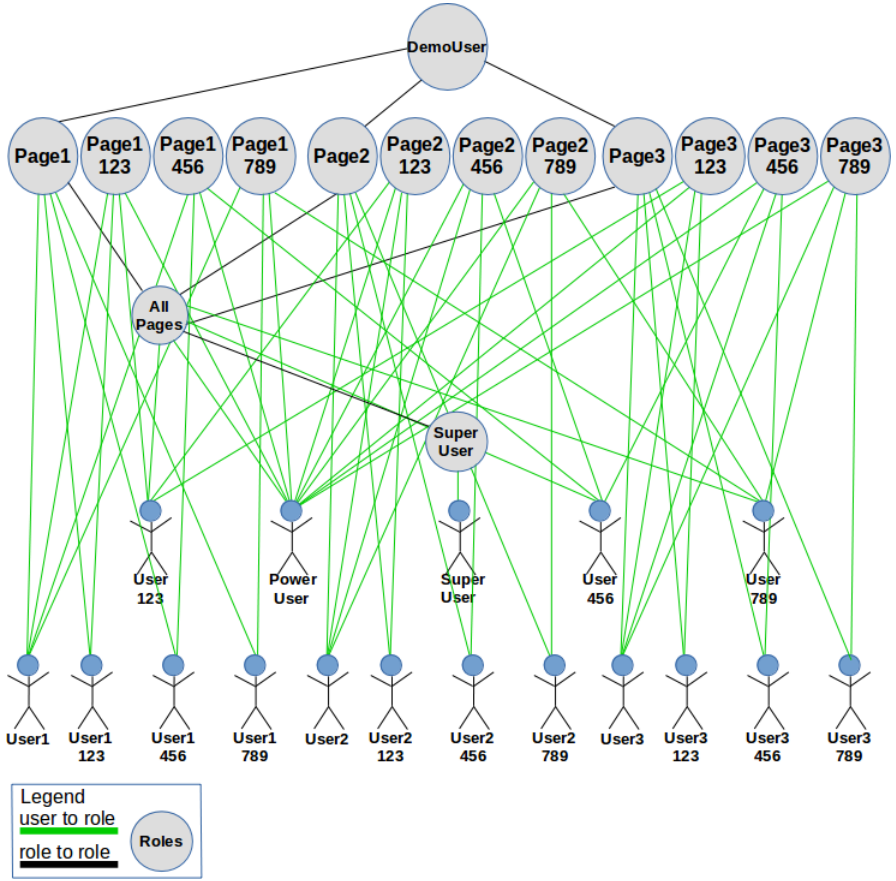
Testing

- Verify security functionality via automation.
- Beware of regressions. Can go unnoticed for weeks, months, years.

https://github.com/shawnmckinney/apache-fortress-demo/.../ApacheFortressDemoSeleniumITCase.java

We still have a problem…

Roles Have Exploded



Number of Roles = sizeof(A) * sizeof(B)

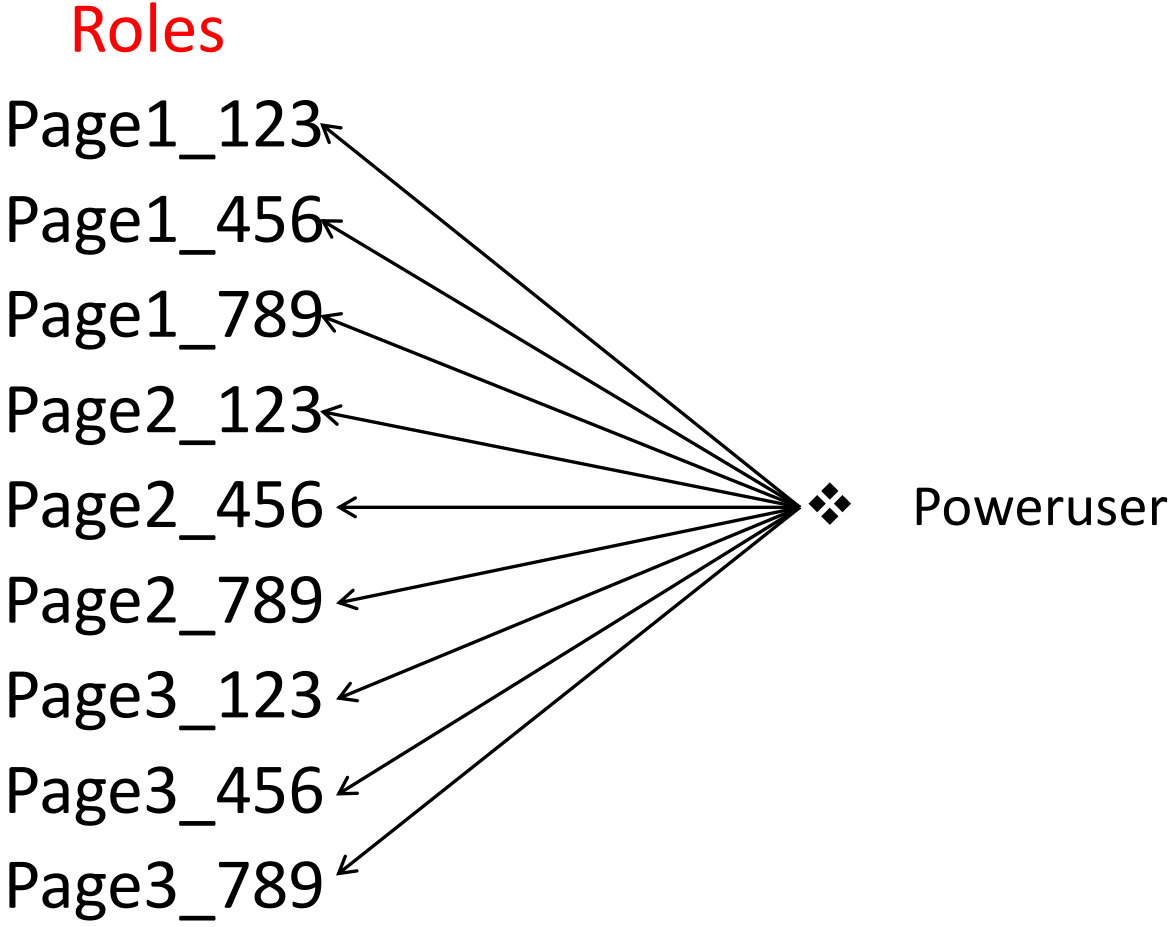
Roles (A)		Relationships (B)
Page1		Customer 123
Page2	*	Customer 456
Page3		Customer 789

=>

Roles

1. Page1-123
2. Page1-456
3. Page1-789
4. Page2-123
5. Page2-456
6. Page2-789
7. Page3-123
8. Page3-456
9. Page3-789

RBAC only


Roles
Page1_123
Page1_456
Page1_789
Page2_123
Page2_456
Page2_789
Page3_123
Page3_456
Page3_789
Poweruser

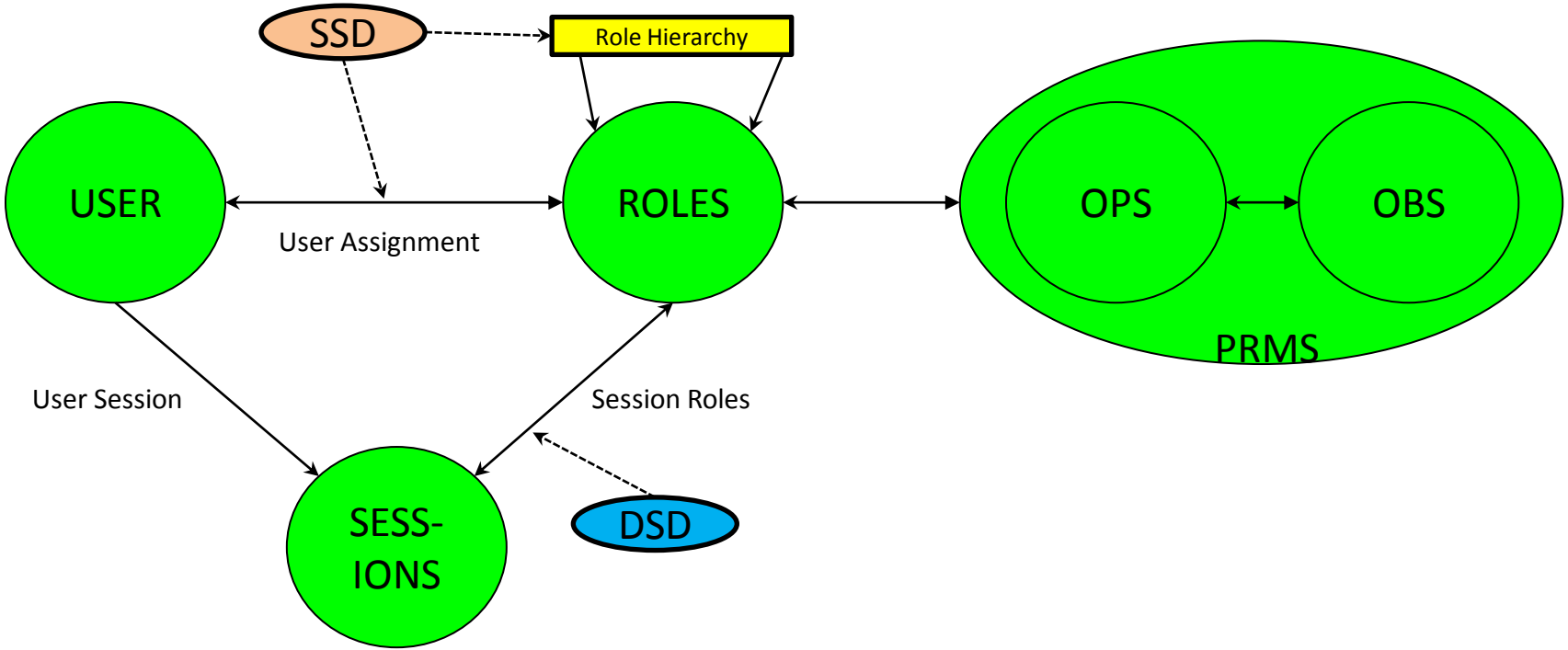
The Solution

Use attributes to constrain under what conditions roles may be activated.

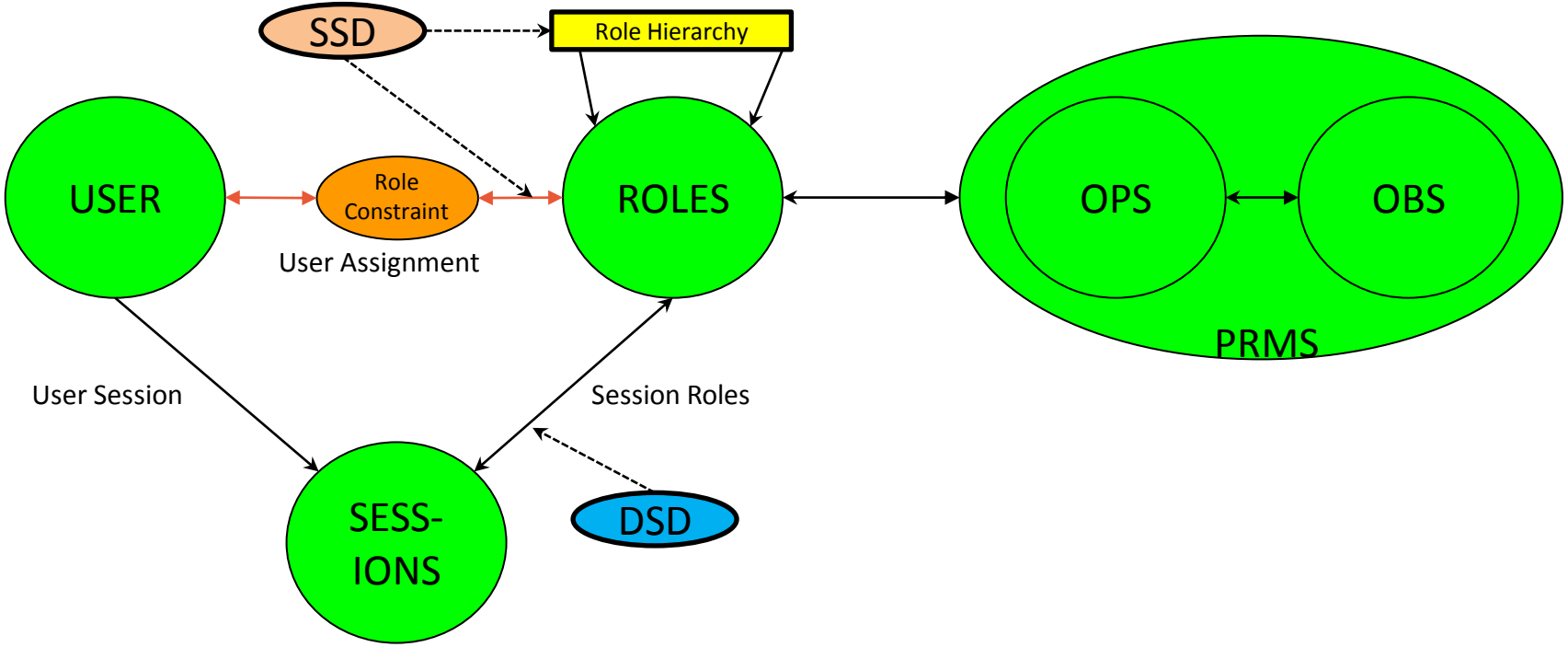
RBAC Policy Enhanced

Role Based Access Control – Policy-Enhanced, ANSI INCITS 494 prescribes the usage of dynamic constraints (runtime) which may be applied to users, roles, operations, objects, and permissions.

Use ANSI RBAC INCITS 359 Specification



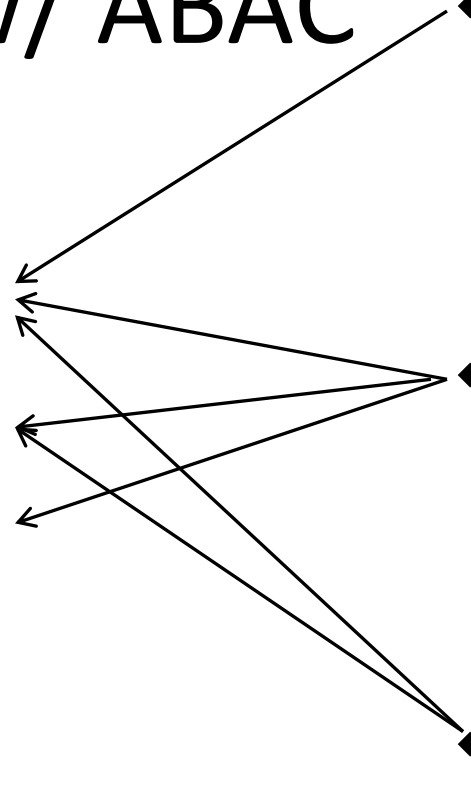
Use ANSI RBAC & ABAC



RBAC w/ ABAC

Roles

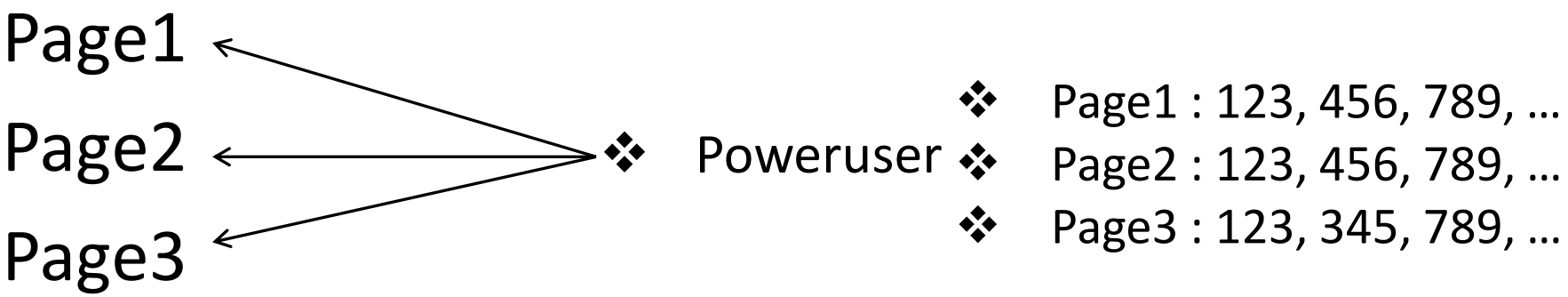
- Cashiers
- Washers
- Managers



- Curly
  - Cashiers: McDonald's,Inout, BurgerKing
- Moe
  - Cashiers: InOut
  - Washers : BurgerKing
  - Managers: McDonald's
- Larry
  - Cashiers: BurgerKing
  - Washers: InOut,McDonald's

RBAC w/ ABAC

Roles



Under the Hood

https://appdevcloudworkshop.github.io/images/introduction/image16.png

RBAC only

- ou=Roles (17)
  - cn=PAGE1_123
  - cn=PAGE1_456
  - cn=PAGE1_789
  - cn=PAGE2_123
  - cn=PAGE2_456
  - cn=PAGE2_789
  - cn=PAGE3_123
  - cn=PAGE3_456
  - cn=PAGE3_789

uid	user123
uidNumber	**1237**
description	Apache Fortress Demo User123 Access all Pages for Customer 123
displayName	test2
ftCstr	user123$0$0000$0000$20090101$20990101$none$none$1234567
ftProps	initAttrArrays:
ftRA	PAGE1_123
ftRA	PAGE2_123
ftRA	PAGE3_123
ftRC	PAGE1_123$0$0000$0000$none$none$none$none$all
ftRC	PAGE2_123$0$0000$0000$none$none$none$none$all
ftRC	PAGE3_123$0$0000$0000$none$none$none$none$all

RBAC w/ ABAC

- ou=Roles (23)
  - cn=ABAC_PAGE1
  - cn=ABAC_PAGE2
  - cn=ABAC_PAGE3

uid	user123
uidNumber	**1254**
description	Apache Fortress Demo User123 Access all Pages for Customer 123
displayName	test2
ftCstr	user123$0$$$$$$$
ftProps	initAttrArrays:
ftRA	ABAC_PAGE1
ftRA	ABAC_PAGE2
ftRA	ABAC_PAGE3
ftRC	ABAC_PAGE1$0$$$$$$$
ftRC	abac_page1$type$USER$customer$123$
ftRC	ABAC_PAGE2$0$$$$$$$
ftRC	abac_page2$type$USER$customer$123$
ftRC	ABAC_PAGE3$0$$$$$$$
ftRC	abac_page3$type$USER$customer$123$

Role Constraints

```
<roleconstraint role="PAGE1"
  key="customer" … />
<roleconstraint role="PAGE2"
  key="customer" … />
<roleconstraint role="PAGE3"
  key="customer" … />
```

https://github.com/shawnmckinney/fortress-abac-demo/blob/master/src/main/resources/fortress-abac-demo-load-policy.xml

User-Role Constraints

```
<roleconstraint userId="User123" role="PAGE1"
  key="customer" value="123" … />

<roleconstraint userId="User123" role="PAGE2"
  key="customer" value="123" … />

<roleconstraint userId="User123" role="PAGE3"
  key="customer" value="123" … />
```

https://github.com/shawnmckinney/fortress-abac-demo/blob/master/src/main/resources/fortress-abac-demo-load-policy.xml

Code Sample

```
// Nothing new here:
User user = new User("curly");

// This is new:
RoleConstraint constraint = new RoleConstraint( );

// In practice we're not gonna pass hard-coded key-values in here:
constraint.setKey( "customer" );
constraint.setValue( "123" );

// This is just boilerplate goop:
List<RoleConstraint> constraints = new ArrayList();
constraints.add( constraint );

try
{
   // Create the RBAC session with ABAC constraint -- customer=123, asserted:
   Session session = accessMgr.createSession( user, constraints );
   ...
}
```

https://github.com/shawnmckinney/fortress-abac-demo/blob/master/src/main/java/com/mycompany/MyBasePage.java

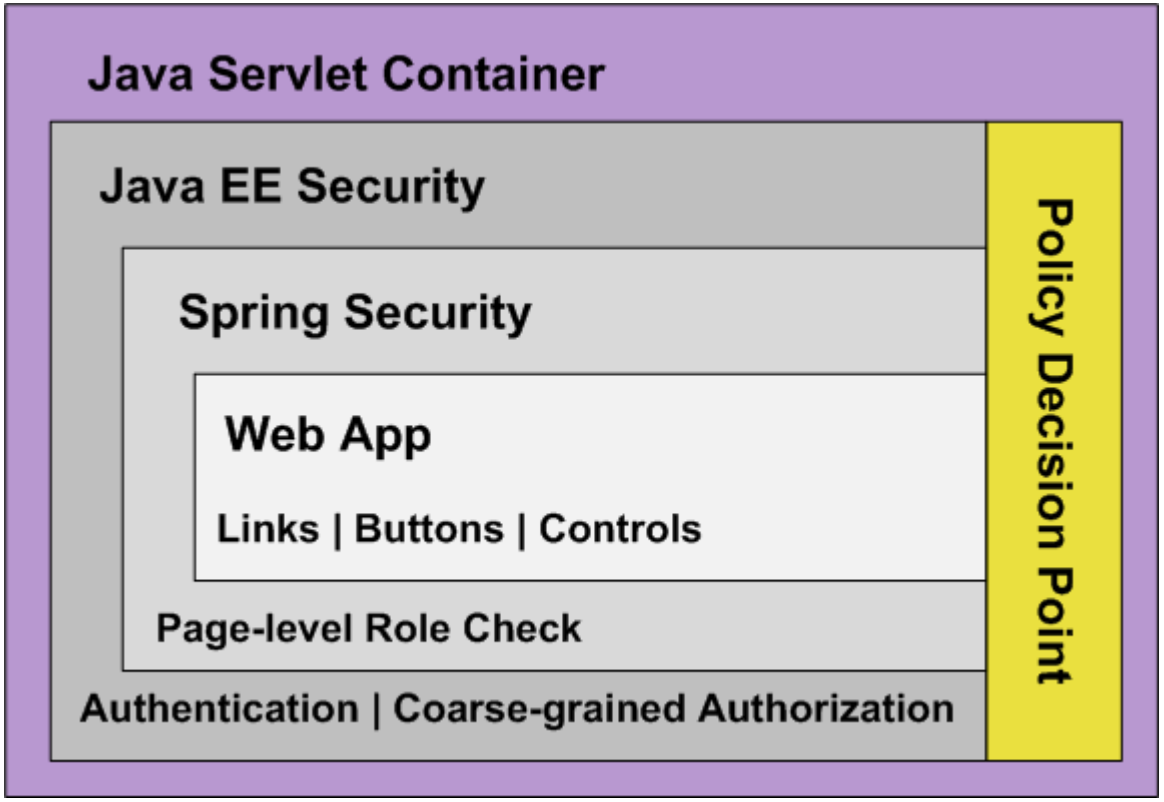
Example #4

Apache

Fortress

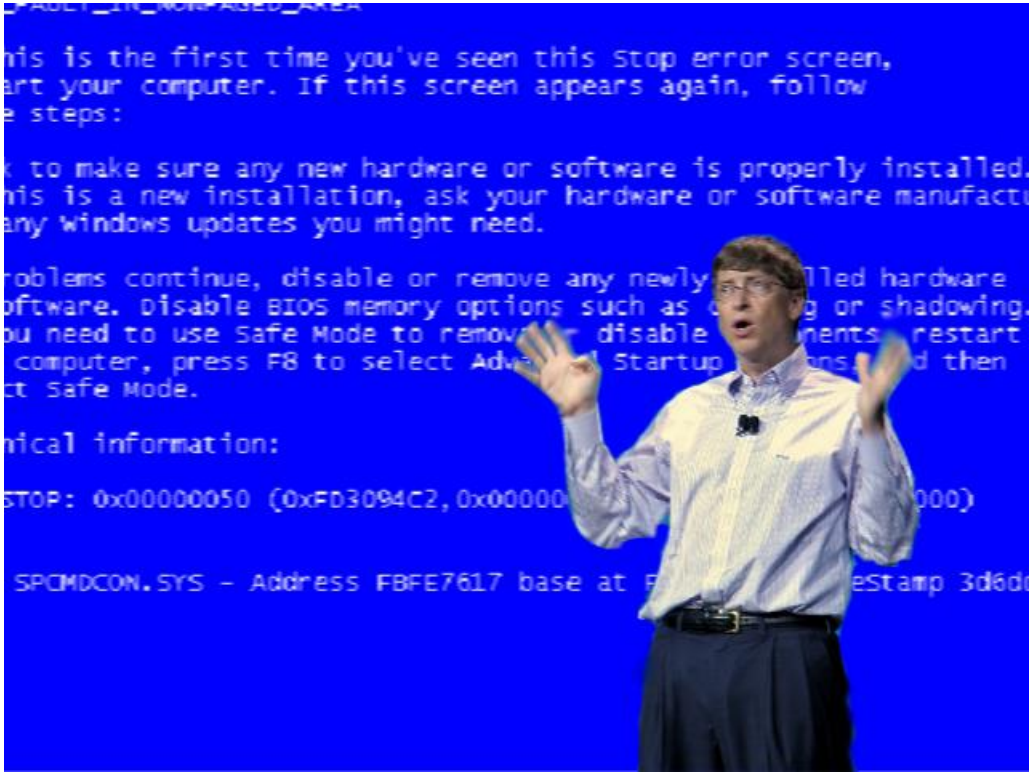
ABAC

Demo



https://github.com/shawnmckinney/fortress-abac-demo

ABAC Demo


his is the first time you've seen this Stop error screen,
art your computer. If this screen appears again, follow
e steps:
to make sure any new hardware or software is properly installed.
his is a new installation, ask your hardware or software manufactu
any Windows updates you might need.
roblems continue, disable or remove any newly
lled hardware
oftware. Disable BIOS memory options such as
or shadowing.
ou need to use Safe Mode to remov
disable
restart
computer, press F8 to select Ad
Startup
then
ct Safe Mode.
nical information:
STOP: 0x00000050 (0xFD3094C2,0x00000
000)
SPCMDCON.SYS - Address FBFE7617 base at F
eStamp 3d6d

Closing Thoughts

1. Never allow users more than they need to do their jobs
   - *Principle of Least Privilege*
2. Apply security controls across many layers
   - *Defense in Depth*
3. RBAC may be combined with ABAC
   - *Fine-grained Authorization*

Examples

1. https://github.com/shawnmckinney/remote-code-execution-sample
2. https://github.com/shawnmckinney/apache-fortress-demo
3. https://github.com/shawnmckinney/role-engineering-sample
4. https://github.com/shawnmckinney/fortress-abac-demo

Bonus:

5. https://github.com/shawnmckinney/rbac-abac-sample
6. https://github.com/shawnmckinney/fortress-saml-demo

Questions

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