Nemesis:
Preventing Web Authentication & Access Control Vulnerabilities

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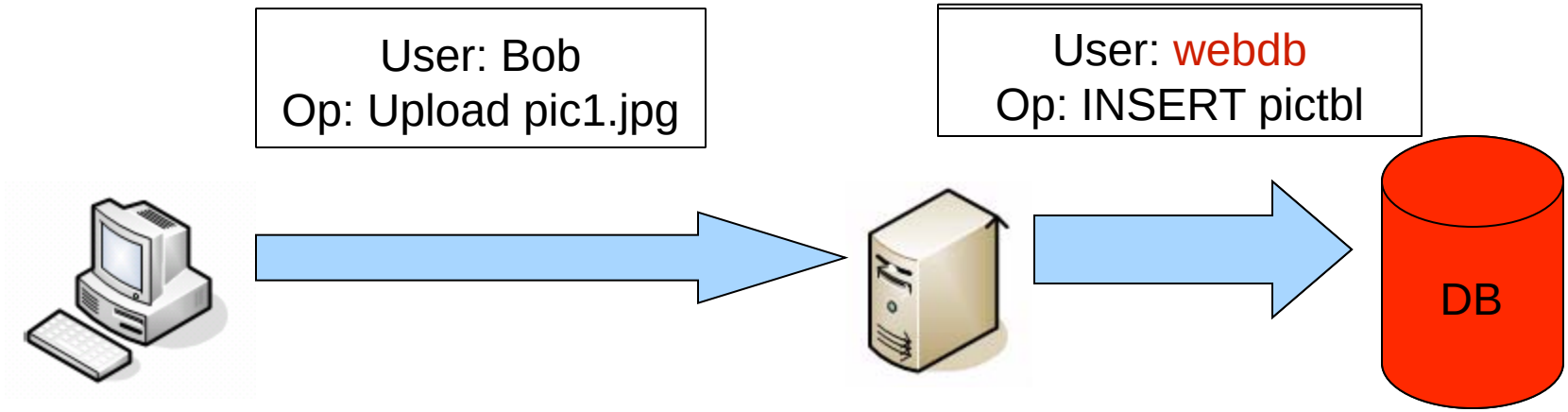
Web Application Overview



FS/DB access executed with full app privileges!

Web Authentication is Broken

- **Semantic Gap** – independent auth sys
  - **Web Authentication vs. DB, FS, LDAP, …**
- Webapps are effectively setuid progs
  - All FS, DB ops have privs of webapp
  - Not privs of webapp **user** (Confused Deputy)
- Programmer must insert auth checks
  - Check web app user before **all** FS/DB op
  - Safe only if programmer is **perfect**

And in the real world…

- Programmers forget auth/ACL checks
  - Authentication/Authorization OWASP Top 10
- Difficult to prevent automatically
  - Each app has its own authentication system
  - Apps have different privilege/ACL systems
- Widespread, highly damaging
  - Vulns usually result in ‘admin’ access to app

Authorization Bypass Vulns

- Resource access without authorization
  - Missing authorization check
  - Incorrect authorization check

```
if(client_authorized($_GET['fileName'])
     openFile($_GET['filename']))
```

Add URL parameter: filename=/etc/passwd

Authentication Bypass Vulns

- Authentication without valid credentials
  - URL/Cookie Validation Error
  - Weak Crypto
  - Ruby on Rails
    - http://n8.tumblr.com/post/117477059/security-hole-found-in-rails-2-3s

```
if (isset($_COOKIE['user']))
    $userName = $_COOKIE['user'];
```

Edit cookie, add name/value pair: 'user=admin‘

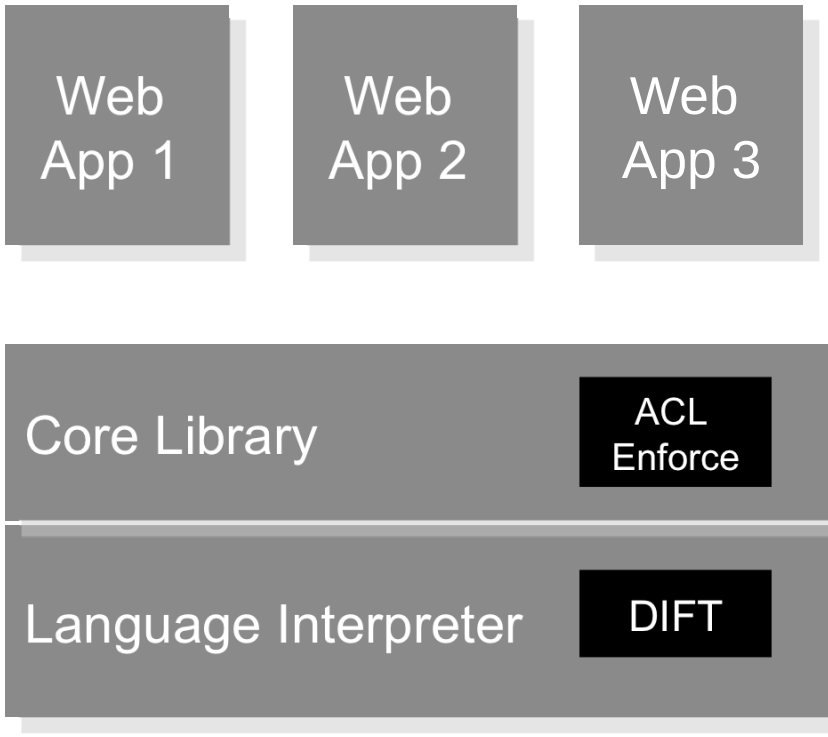
Ideal Auth/ACL System

- Only authenticates correctly/safely
  - No authentication bypass attacks
- Always enforces ACLs correctly
  - No authorization bypass attacks
- Existing systems fail on both counts
  - May authenticate unsafely if vulnerable
  - Do not enforce ACLs automatically

Nemesis Overview

- Stops authentication, authorization atks
  - Without requiring app auth code rewrites
- **Infers** when authentication done safely
  - **Use DIFT to track auth credentials**
- **Enforces** ACLs automatically on file/DB
  - **ACLs specify privs for <u>web clients</u>**

Nemesis System Overview



Intercept I/O ops for File ACLs
Intercept SQL ops for DB ACLs

Automatic auth inference
2 tag bits per object
Tag prop on all object ops

Safe Authentication Inference

- Propagate user credential, taint bits
  - 2 tag bits per object (String, integer, etc)
- **Infer** when auth occurs safely
  - Tainted info compared equal to auth cred
  - Add check to string or array comparison op
- Record **authentication inferred** user
  - Auth bypass attacks do not change this user

Authentication Example

```
$user = $_GET['username']
$user = mysql_real_escape_string($user)
$pw = md5sum($_GET['password'])

$realpw = $db->query("SELECT pw FROM
    users WHERE userName =" + $user +
    "'"

if ($pw == $realpw) {
```

Authenticated!

T	P	Variable
		$user
		$pw
		$realpw

Authorization Enforcement

- Enforce ACLs on FS, DB access
  - Apply to **authentication inferred user**
- Restrict DB table/row, file access
  - Many tables store per-user rows
- Taint information used in some rules
  - New user registration
  - Password change

Attack Prevention

- Authorization Bypass
  - Nemesis ACLs enforced automatically
  - Not dependent on any app-enforced checks
- Authentication Bypass
  - Auth inference not affected by attack
    - Inference requires user input == password
  - **ACLs check inferred user**
  - Prevents access to any privileged resource!

Configuration Requirements

- Authentication inference
  - Table/column info for auth credentials
- ACL enforcement
  - ACL from sysadmin for DB, File access
- Future work
  - Current configuration provided by admin
  - Log DB, File ops along with inferred user
  - Auto-generate ACLs from logs

Nemesis Prototype

- Added DIFT support to PHP interpreter
  - Password, Taint bits for String, int, etc
  - Assume Raksha checking OS & PHP interpreter for low-level attacks
- Auth inference on string comparison
  - ==, != operators
- Don't have a full SQL query rewriter
  - Had to manually insert DB checks

Experimental Results

Application	Size (Lines)	Auth Lines Added	ACL Check Lines Added	Attack Prevented
Php iCalendar	13,500	3	22	Auth Bypass
PhpStat	12,700	3	17	Missing ACL Check
Bilboblog	2,000	3	11	Incorrect ACL Check
phpFastNews	500	5	17	Auth Bypass
Linpha Gallery	50,000	15	49	SQL Injection in Password Check
DeluxeBB	22,000	6	143	Missing ACL Check

No discernible performance overhead

Authenticatication Bypass: Bilboblog

- Internal login script internet accessible
  - Admin username and password undefined
- PHP + Register Globals = Fail
  - Undefined vars initialized by URL params
- Attacker supplies the admin password!
  - Ensures the ‘submitted’ password is equal

Protecting Bilboblog

- Vulnerable app does not perform auth
  - Compares user input to user input
- Attack has no effect on shadow auth
  - Attacker-supplied admin password is tainted
  - Does not have user credential bit set
- Access to privileged resources denied
  - ACL checks use shadow authenticated user

Authorization Bypass: DeluxeBB

- Forum supports private messages
  - Stored in DB, restricted to sender/receiver
- Invalid access control check
  - Malformed cookies bypass check entirely
- Attacker forges cookies
  - Can read arbitrary user's private messages

Protecting DeluxeBB

- Nemesis does not parse app cookies
  - Maintains its own shadow auth cookies
- DeluxeBB has row ACL for pm table
  - ‘From’ or ‘To’ field = shadow auth user
- Exploit rendered harmless
  - Only read row if From/To shadow auth user
  - No information leaks can occur

Future Work

- Develop full language for ACLs
- Automate SQL query rewriting for ACLs
  - Database views/triggers (see related work)
  - MySQL Proxy
- Automate ACL generation
  - Parse DB, File access logs
  - Infer authentication rules

Conclusion

- Web authentication is broken
  - **Semantic gap** between Web App, DB & FS
- Nemesis **infers** safe authentication
  - When user input compared equal to password
- Nemesis **enforces** authorization
  - ACLs apply to authentication inferred user
- Validated using real-world PHP Apps
  - Prevented authentication & authorization bypass