Improving Logging to Reduce Permission Over-Granting Mistakes

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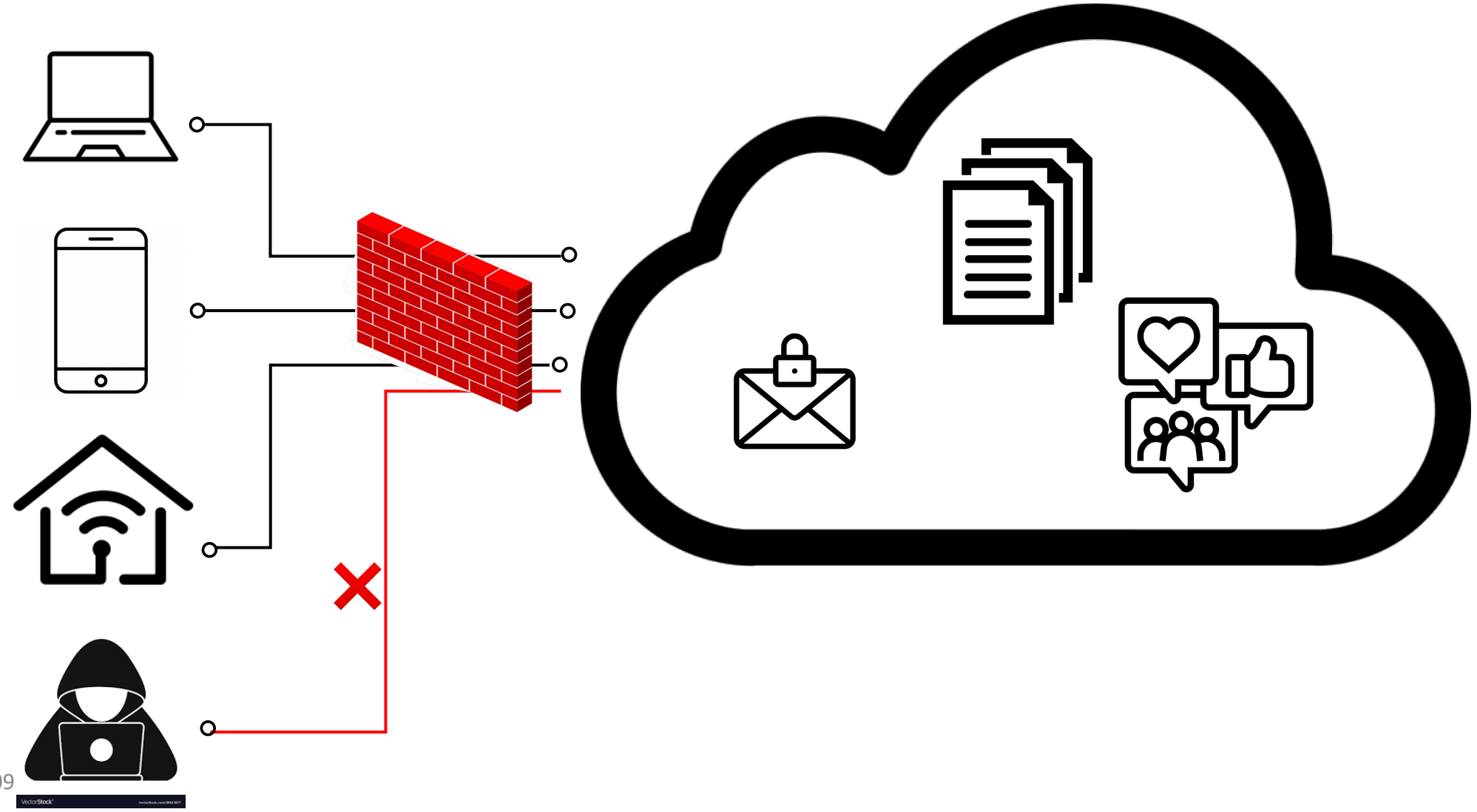
Access Control Protects User Data on Cloud



Prevalent misconfigurations cause newsworthy data leaks

Oct 6, 2021, twitch suffered from a major data breach including **source code and creator payouts**, because a hacker accessed the company's servers due to a **server configuration change.**

Mar 9, 2022, **70% of tested servicenow instances** were vulnerable because **misconfigured customer-managed Access Control Lists (ACLs)** and overprovisioning of permissions to guest users**.**

Apr. 12, 2022, **13 million** users' records were found public because the **misconfiguration of Content Management System (CMS) database**.

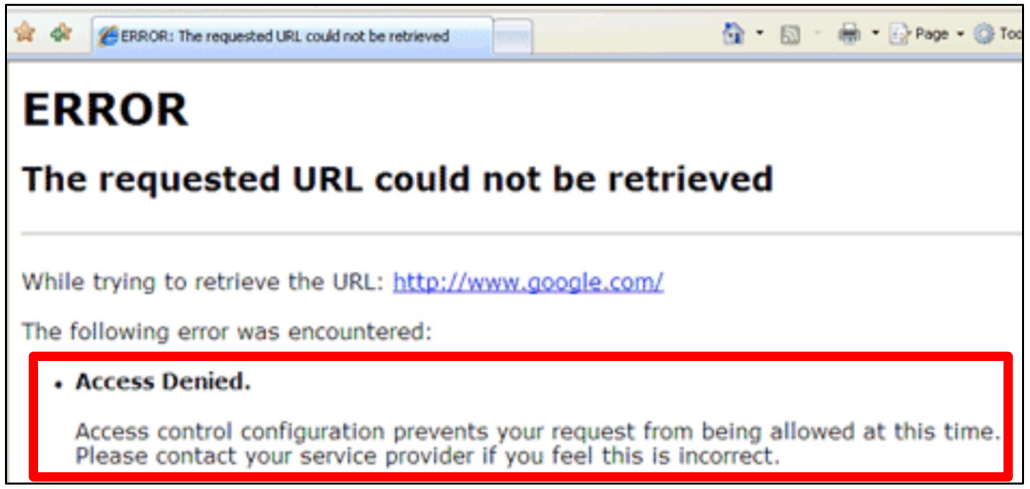
Misconfigurations introduced in solving access-denied issues

user

Users' legitimate access falsely denied by servers

server

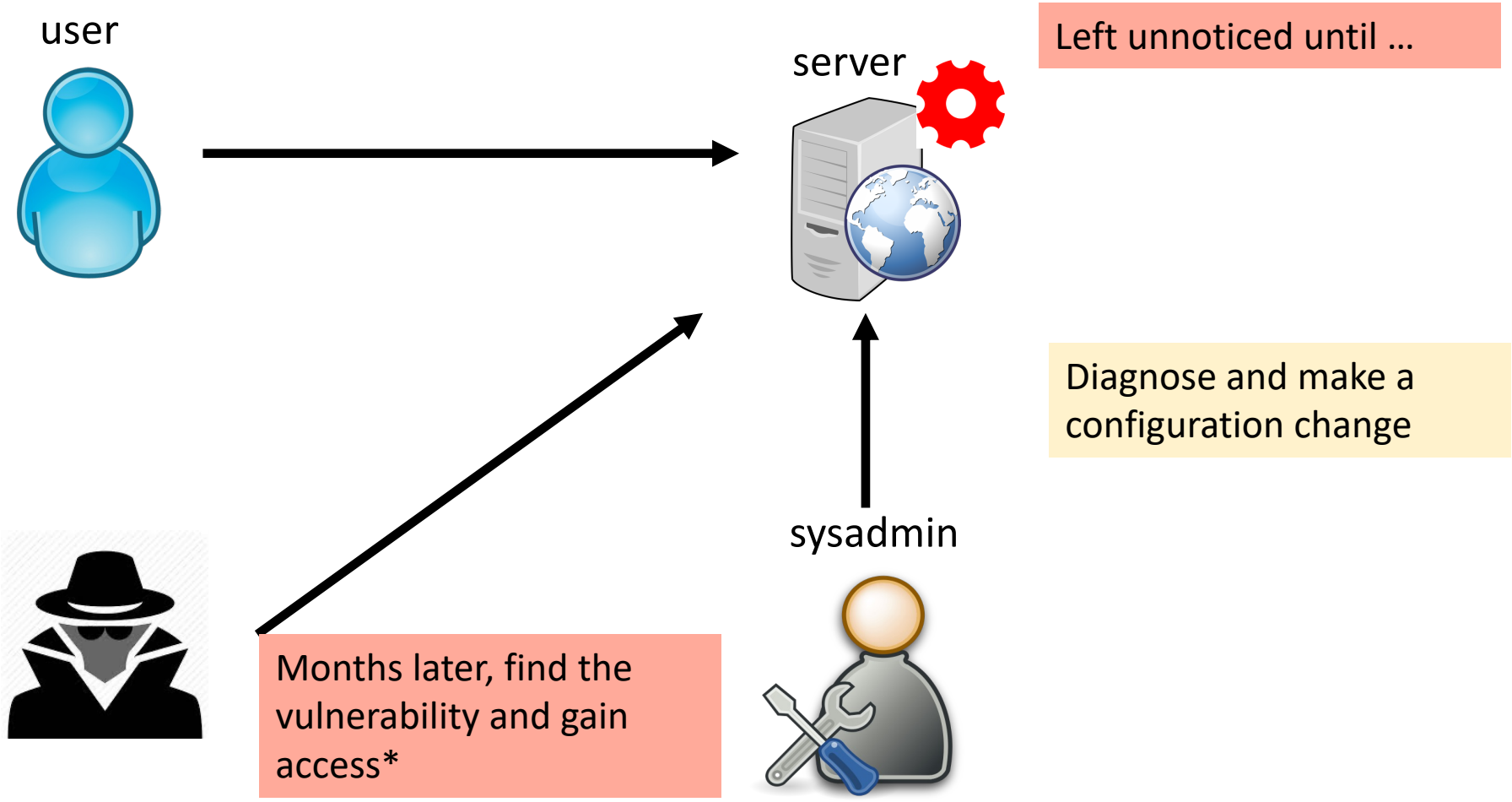
Left unnoticed until …



Diagnose and make a configuration change

sysadmin

Misconfigurations may be introduced in solving access-denied issues



* https://www.varonis.com/blog/data-breach-response-times/

Log messages are the main feedback for sysadmins

- Log messages help sysadmins develop the precise understanding of the root cause.

  - **87.0%** of sysadmins check logs
  - only **1.6%** of sysadmins looked at source code

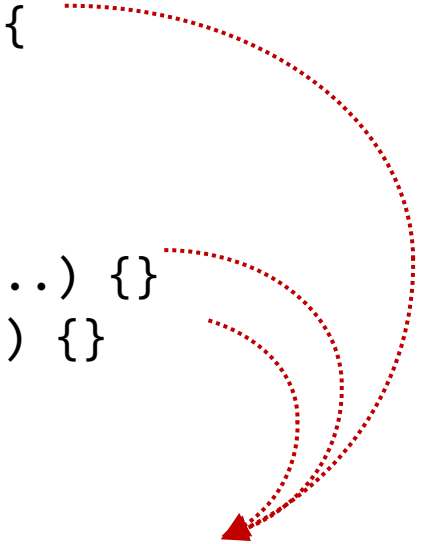
*How Do System Administrators Resolve Access-Denied Issues in the Real World?, CHI'17

Poor logging practice in server software

1. The log messages do not contain specific/complete information

```
status ip_check_authorization(request *r, ...) {
  ... // <- check request's IP w/ config.
  return AUTHZ_DENIED;
}
status method_check_authorization(request *r, ...) {}
status host_check_authorization(request *r, ...) {}


...
if (auth_result == AUTHZ_DENIED) {
  ap_log_rerror(APLOG_ERR, r, APLOGNO(01631)
   "%s: authorization failure for \"%s\": ", r->user, r->uri);
```



/* httpd-2.4.46: modules/aaa/mod_authz_core.c */

Poor logging practice in server software

1. The log messages do not contain specific/complete information
2. Developers may miss access-deny locations.

```
/* Cherokee-1.2.103: cherokee/config_reader.c*/
dir = cherokee_opendir (path->buf);
if (dir == NULL)
        return ret_error;
```


Silently ignoring the denied access

Poor logging practice in server software

1. The log messages do not contain specific/complete information
2. Developers may miss access-deny locations.

```
/* Cherokee-1.2.103: cherokee/config_reader.c*/
dir = cherokee_opendir (path->buf);
if (dir == NULL)
+    LOG_CRITICAL (“Could not open directory ‘%s’, check
the server user and file permissions.”, path->buf);
     return ret_error;
```

How good are the logging practices in the server software?

Understanding real-world server software

Q1: How often do server software have log messages when the access is denied?

Q2: Do the log messages have complete information related to the denied access?

Q3: How do software developers add or update access-deny log messages?

Study preparation

- Find access-deny locations and analyze the log messages
- Target on server software
  - 5 server programs: web server, database, FTP, NFS

Finding 1

Q1: How often do server software have no log messages when the access is denied?

A: Even in mature software, 14.0% to 70.5% of cases have no log messages when an access is denied.

Application	No logs at default level	%
Apache httpd	63	35.4%
PostgreSQL	107	22.2%
Vsftpd	10	14.0%
NFS-ganesha	43	70.5%
Proftpd	209	58.7%

Specific information for a request

- Q2: Do the log messages have complete information related to the denied access?

	subject	action	object
Web server	Web server user	GET, POST	html, pdf, …
Database	DB user	SELECT, UPDATE	table, column, …

Finding 2

Q2: Do the log messages have complete information related to the denied access?

A1: Servers have subject, action, or object at different levels.

Application	Subject		Action		Object	
Apache httpd	13	11.3%	90	78.3%	97	84.3%
PostgreSQL	99	26.5%	132	36.9%	267	71.4%
Vsftpd	2	3.3%	41	67.2%	15	100%
NFS-ganesha	15	60.0%	24	96.0%	18	68.0%
Proftpd	0	0%	146	100%	146	100%

Finding 2

Q2: Do the log messages have complete information related to the denied access?

A1: Servers have subject, action, or object at different levels.

A2: The information is available at the same function at the denied location.

Application	Subject		Action		Object		In same func.	
Apache httpd	13	11.3%	90	78.3%	97	84.3%	112	97.3%
PostgreSQL	99	26.5%	132	36.9%	267	71.4%	357	95.5%
Vsftpd	2	3.3%	41	67.2%	15	100%	61	100%
NFS-ganesha	15	60.0%	24	96.0%	18	68.0%	17	68.0%
Proftpd	0	0%	146	100%	146	100%	146	100%

Finding 3

Q3: How do software developers add/update access-deny log messages for sysadmins?

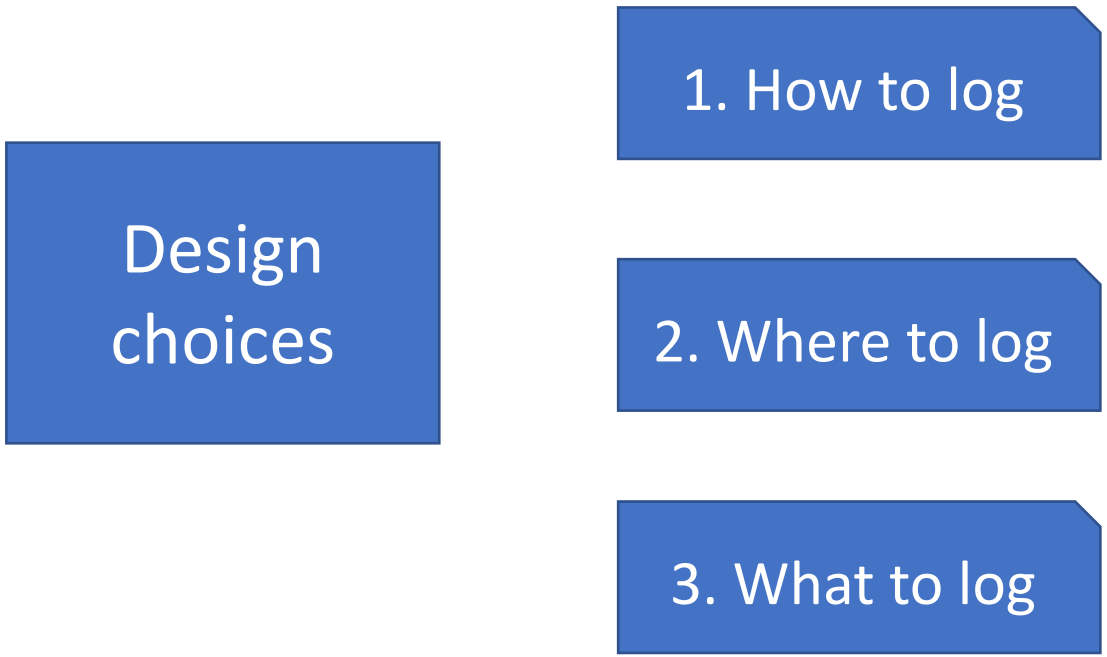
A: Access-deny logging practice is ad-hoc and many existing log messages are added as afterthoughts.

Application	Add logs	Revise logs
Apache httpd	40	511
PostgreSQL	165	1728
Vsftpd	-	-
NFS-ganesha	7	344
Proftpd	33	1209

Can we automatically improve access-deny logging?

Our solution: SecLog

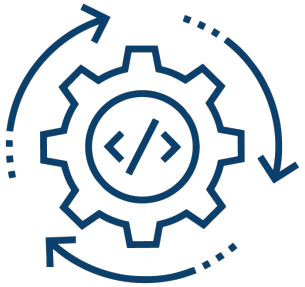
- To help developers to enhance existing log messages and insert missing log messages
- To provide guidance for sysadmins to fix access-deny issues without over-granting permissions



Challenge 1: How to log

- Manual solution
  - Rely on developers to **manually** log
    - Cons 1: Many logging locations
    - Cons 2: Manually examine call chains to collect info

- SecLog solution
  - **Automated** static analysis tool to assist the logging process
  - Can be **integrated** in development process



CI / CD

Challenge 2: Where to log (1)

1. Where to find access control check (ACC) locations?

```
// ACC function in Cherokee web server
ret = cherokee_mkdir_p_perm (&path, 0775, W_OK);
if (ret != ret_ok) {
    LOG_CRITICAL("Cannot create the '%s' directory", path);
        return ret_error;
}
// ACC function in PostgreSQL
aclresult = pg_class_aclcheck(TableID, GetUserId(), ACL_SELECT);
if (aclresult != ACLCHECK_OK)
        aclcheck_error(aclresult, ACL_SELECT, TableID);
```

Used at 5 locations

Used at 34 locations

SecLog solution:

- Use ACC functions to find access-control check locations (require developer annotation)

Challenge 2: Where to log (2)

2. Where to place the log statements
   - Inside the ACC function
   - At the ACC function's call site

	Inside the ACC function	**At the ACC function's call site**
Pros	• Low analysis cost	• More comprehensive info
Cons	• May miss the info at call site	• More analysis cost

Challenge 2: Where to log (2)

2. Where to place the log statements
   - Inside the ACC function
   - **At the ACC function's call site**

	Inside the ACC function	**At the ACC function's call site**
Pros	• Low analysis cost	• More comprehensive info
Cons	• May miss the info at call site	• More analysis cost

Challenge 3: What to log

- The critical information to insert into log statements
  1. Inside the ACC function
  2. At the ACC function's call site
- Approach
  - Extract relevant variables with *static analysis*

Challenge 3: What to log

1. Inside the ACC function
   - From the return value, perform backward slicing
   - Extract the reasons for each deny

return val 1

Access control check function

```
cherokee_mkdir_p_perm(buffer_t* dir, mode, perm){
  re = cherokee_stat(dir->buf, &foo);
  if (re != 0) {/*if not exist, create the dir.*/
    ret = cherokee_mkdir_p(dir, mode));
    if (ret != ret_ok)
      return ret_error;
  }
  /* dir exist, check permissions */
  ret = cherokee_access(dir->buf, perm);
  if (ret != ret_ok)
    return ret_deny;
  return ret_ok;}
```

Challenge 3: What to log

1. Inside the ACC function
   - From the return value, perform backward slicing
   - Extract the reasons for each deny

return val 1

Access control check function

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  /* dir exist, check permissions */
  ret = cherokee_access(dir->buf, perm);
  if (ret != ret_ok)
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  return ret_ok;}
```

Challenge 3: What to log

1. Inside the ACC function
   - From the return value, perform backward slicing
   - Extract the reasons for each deny

return val 1

2. At the function's call site
   - From the relevant variables, perform data dependency analysis

return val 2

return val 3

Access control check function

```
cherokee_mkdir_p_perm(buffer_t* dir, mode, perm){
  re = cherokee_stat(dir->buf, &foo);
  if (re != 0) {/*if not exist, create the dir.*/
    ret = cherokee_mkdir_p(dir, mode));
    if (ret != ret_ok)
      return ret_error;
  }
  /* dir exist, check permissions */
  ret = cherokee_access(dir->buf, perm);
  if (ret != ret_ok)
    return ret_deny;
  return ret_ok;}
```

Evaluation

- Log improvement
  - Overrall results
  - Helpfulness of identifiedvariables
- User study
- Performance overhead
- Adoption efforts

Evaluation

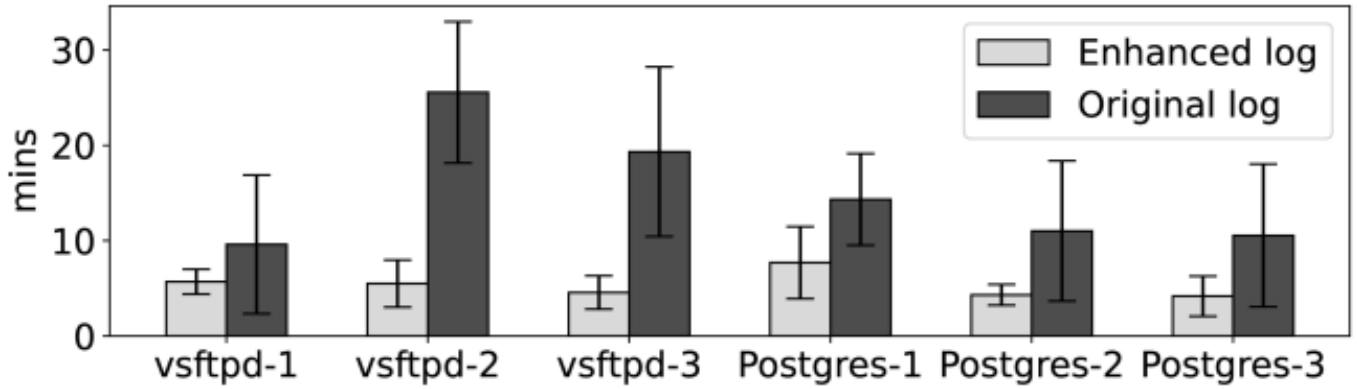
- In total, SecLog inserts 380 new access-deny log statements and enhances 550 existing ones
- Currently, **70 of 114 submitted log improvements have been accepted**

	Existing Logs		New Logs	
App	#	# new vars	#	# vars
Apache httpd	93	5.62	41	7.05
PostgreSQL	203	2.61	121	4.16
vsftpd	39	1.67	9	2.44
NSF-granshea	8	3.00	20	5.9
Proftpd	145	4.03	111	4.13
Postfix	8	8.75	36	14.28
HAProxy	3	3.33	10	6.40
Cherokee	11	2.18	23	3.35
redis	11	1.82	6	3.00
mSQL	19	2.00	-	-

Evaluation: User study

- User study
  - Recruit **32 professionals**
  - 3 problems each for vsftpd/PostgreSQL
  - The only difference is the log message

# (%) of insecure solutions	Problem 1		Problem 2		Problem 3	
	Original	SecLog	Original	SecLog	Original	SecLog
vsftpd	1 (6.25%)	0 (0.0%)	6 (37.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PostgreSQL	8 (50.0%)	0 (0.0%)	4 (25.0%)	1 (6.25%)	8 (50%)	0 (0.0%)



SecLog-enhanced log group 3x faster

Conclusion

- An observation study on existing access-deny logging practice
  - Better logging for access control administration
- Design choices for improving access-deny logging
  - How to log
  - Where to log
  - What to log

Limitations

- Imprecise intra-procedure static analysis
- SecLog can not automatically generates natural language log messages
- SecLog does not fix the problems for sysadmins.

Thank you

Q&A