Chapter 14: Protection

Prof. Martín Vigil

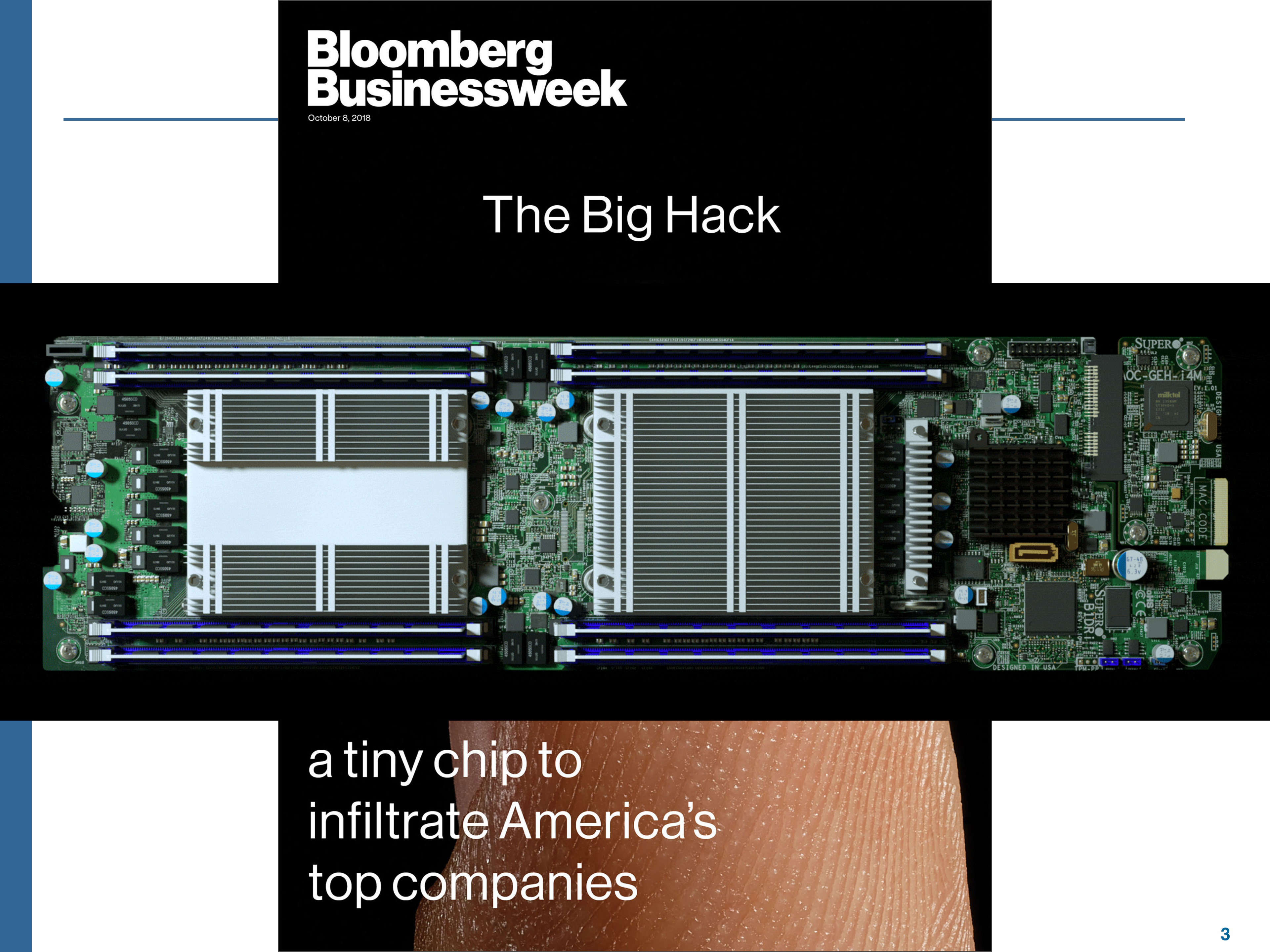
Adaptado de Silberschatz, Galvin & Gagne 2013

Goals of Protection

- In one protection model, computer consists of a collection of objects, hardware or software (i.e., resources)
- Each object has a unique name and can be accessed through a well-defined set of operations
- Protection problem - ensure that each object is **accessed** correctly and only by those processes that are allowed to do so

Authorization ~ Access control =

prevent an unauthorized user from accessing a resource


Bloomberg
Businessweek
October 8, 2018
The Big Hack
a tiny chip to
infiltrate America's
top companies

Controle de acesso: exemplos

Juniper Routers Compromised By Hardcoded Backdoor Password In ScreenOS

By Matthew Buchanan

Posted on December 19, 2015

Thought you were safe from the Fortinet SSH backdoor? Think again

More devices are dodgy and hackers are cruising for targets

Principles of Protection

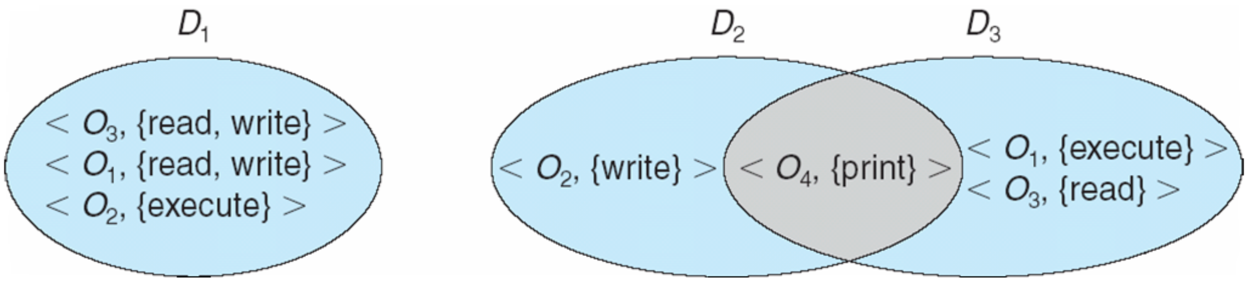
- Guiding principle – **principle of least privilege**
  - Programs, users and systems should be given just enough **privileges** to perform their tasks
  - Limits damage if entity has a bug, gets abused
  - Can be static (during life of system, during life of process)
  - Or dynamic (changed by process as needed) – **domain switching**, **privilege escalation**

Principles of Protection (Cont.)

- Must consider "grain" aspect
  - Rough-grained privilege management easier, simpler, but least privilege now done in large chunks
    - For example, traditional Unix processes either have abilities of the associated user, or of root
  - Fine-grained management more complex, more overhead, but more protective (***not always…***)
    - File ACL lists, RBAC
- Domain can be user, process, procedure

Domain Structure

- Access-right = <*object-name*, *rights-set*>
  where *rights-set* is a subset of all valid operations that can be performed on the object
- Domain = set of access-rights

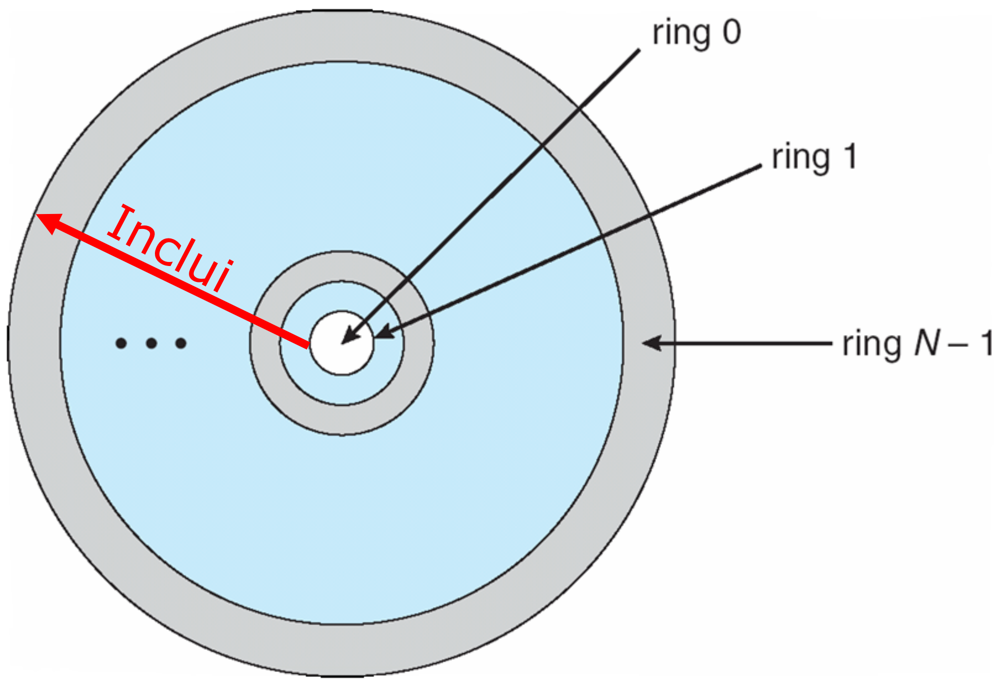


Domain Implementation (UNIX)

- Domain = user-id
- Domain switch accomplished via file system
    - Each file has associated with it a domain bit (setuid bit)
    - When file is executed and setuid = on, then user-id is set to owner of the file being executed
    - When execution completes user-id is reset
- Domain switch accomplished via passwords
    - `su` command temporarily switches to another user's domain when other domain's password provided
- Domain switching via commands
    - `sudo` command prefix executes specified command in another domain (if original domain has privilege or password given)

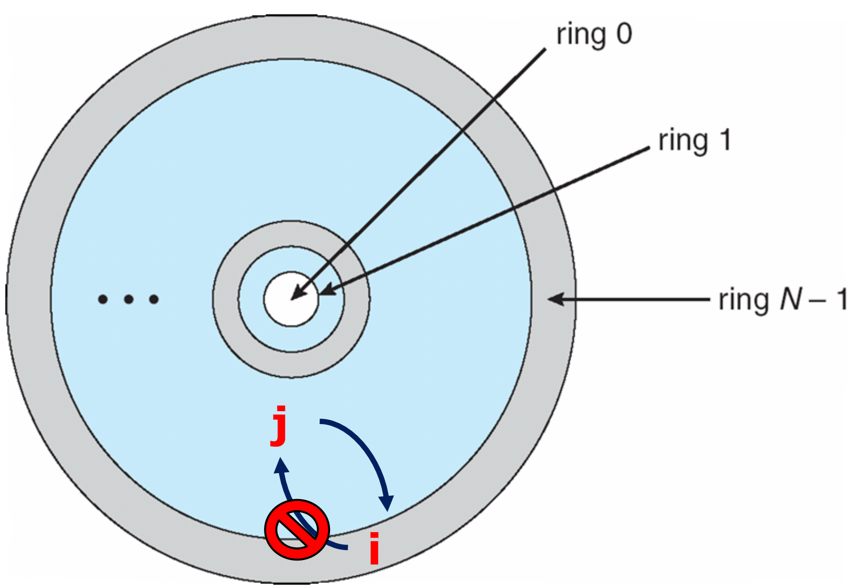
Domain Implementation (MULTICS)

- Let D_i and D_j be any two domain rings
- If $i > j \Rightarrow D_i \subseteq D_j$
  - *A process in D_j has more privileges than a process in D_i*



Multics Benefits and Limits

- Ring / hierarchical structure provided more than the basic kernel / user or root / normal user design
- Fairly complex -> more overhead
- But does not allow strict need-to-know
  - Object accessible in D_j but not in D_i, then ***j*** must be < ***i***
  - But then every segment accessible in D_i also accessible in D_j



Access Matrix

- View protection as a matrix (**access matrix**)
- Rows represent domains
- Columns represent objects
- **`Access(i, j)`** is the set of operations that a process executing in Domain$_i$ can invoke on Object$_j$

object / domain	F_1	F_2	F_3	printer
D_1	read		read	
D_2				print
D_3		read	execute	
D_4	read write		read write	

Use of Access Matrix

- If a process in Domain D_i tries to do "op" on object O_j, then "op" must be in the access matrix
- User who creates object can define access column for that object
- Can be expanded to dynamic protection
  - Operations to add, delete access rights
  - Special access rights:
    - *owner of* O_i
    - *copy op from* O_i *to* O_j *(denoted by "*")*
    - *control –* D_i *can modify* D_j *access rights*
    - *transfer – switch from domain* D_i *to* D_j
  - *Copy* and *Owner* applicable to an object
  - *Control* applicable to domain object

Access Matrix with *Copy* Rights

object / domain	F_1	F_2	F_3
D_1	execute		write*
D_2	execute	read*	execute
D_3	execute		

(a)

* = pode copiar

object / domain	F_1	F_2	F_3
D_1	execute		write*
D_2	execute	read*	execute
D_3	execute	read	

(b)

* removido (cópia limitada)

Access matrix with owner rights

object / domain	F_1	F_2	F_3
D_1	owner execute		write
D_2		read* owner	read* owner write
D_3	execute		

(a)

Dono acrescentou write* a si mesmo

object / domain	F_1	F_2	F_3
D_1	owner execute		write
D_2		owner read* write*	read* owner write
D_3		write	write

Access Matrix

object / domain	F_1	F_2	F_3	laser printer	D_1	D_2	D_3	D_4
D_1	read		read			switch		
D_2				print			switch	switch
D_3		read	execute					
D_4	read write		read write		switch			

Usuários em D2
podem “passar”
pra D3

Access Matrix

object / domain	F_1	F_2	F_3	laser printer	D_1	D_2	D_3	D_4
D_1	read		read			switch		
D_2				print			switch	switch control
D_3		read	execute					
D_4	write		write		switch			

D2 pode modificar
direitos de D4

Use of Access Matrix (Cont.)

- **Access matrix** design separates mechanism from policy
  - Mechanism
    - Operating system provides access-matrix + rules
    - If ensures that the matrix is only manipulated by authorized agents and that rules are strictly enforced
  - Policy
    - User dictates policy
    - Who can access what object and in what mode
- But doesn't solve the general confinement problem (viz., no information initially held in an object can migrate outside of its execution environment). This problem has not been solved yet.

Implementation of Access Matrix

- Generally, a sparse matrix
- Option 1 – Global table
  - Store ordered triples **`<domain, object, rights-set>`** in table
  - A requested operation M on object O_j within domain D_i -> search table for $< D_i, O_j, R_k >$
    - with $M \in R_k$
  - But table could be large -> won't fit in main memory
  - Difficult to group objects (consider an object that all domains can read)

Domain	O_1	O_2	...	O_n
D_1	R_{11}	R	...	R_{1n}
D_2	R_{21}		...	R_{2n}
...	...		...	...
D_n	R_{n1}		...	R_{nn}

Implementation of Access Matrix (Cont.)

- Option 2 – Access **lists for objects**
  - Each column implemented as **an access list for one object**
  - Resulting per-object list consists of ordered pairs `<domain, rights-set>` defining all domains with non-empty set of access rights for the object
  - Easily extended to contain default set -> If M ∈ **default set of access right**, also allow access

$O_1 \rightarrow \langle D_1, R_{11} \rangle$
$O_2 \rightarrow \langle D_1, R_{12} \rangle, \langle D_2, R_{22} \rangle$
...
$O_n \rightarrow \langle D_2, R_{2n} \rangle, \ldots, \langle D_1, R_{nn} \rangle$

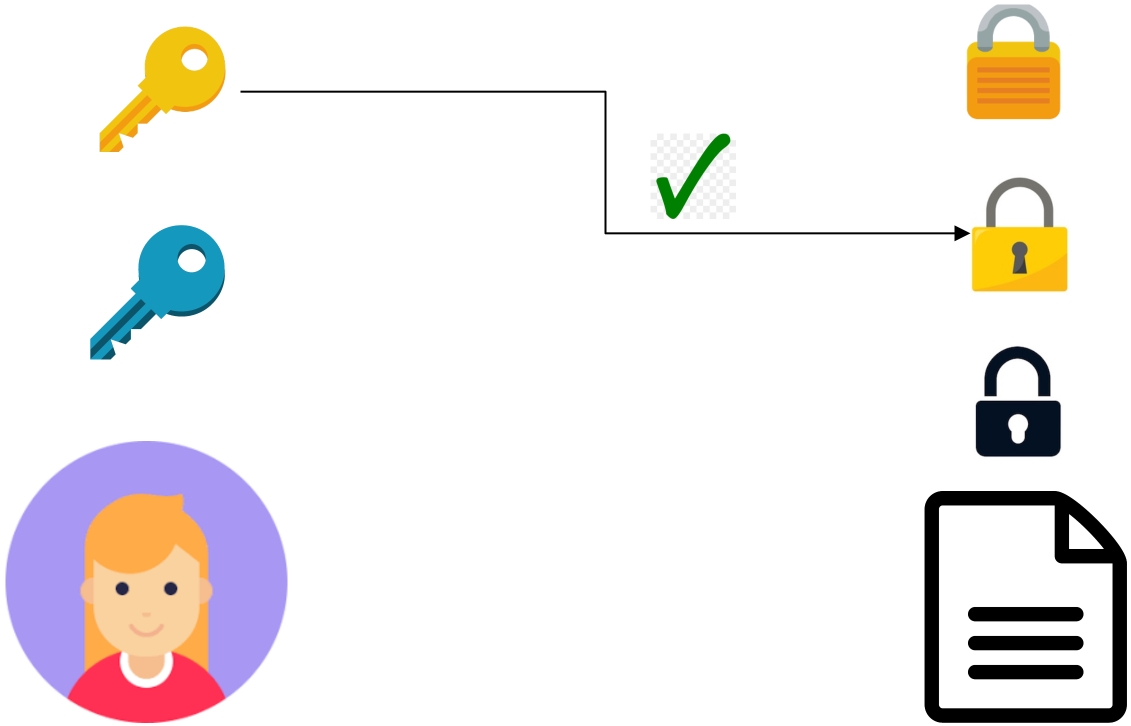
Implementation of Access Matrix (Cont.)

- Option 3 – Capability **list for domains**
  - Instead of object-based, list is **domain based**
  - **Capability list** for domain is list of objects together with operations allows on them
  - Object represented by its name or address, called a **capability**
  - Execute operation M on object O_j, process requests operation and specifies capability as parameter
    - Possession of capability means access is allowed
  - Capability list associated with domain but never directly accessible by domain
    - Rather, protected object, maintained by OS and accessed indirectly
    - Like a "secure pointer"
    - Idea can be extended up to applications

$D_1 \rightarrow \langle O_1, R_{11} \rangle,$
$D_2 \rightarrow \langle O_1, R_{12} \rangle, \langle O_2, R_{22} \rangle, \ldots, \langle O_1, R_{2n} \rangle$

Implementation of Access Matrix (Cont.)

- Option 4 – Lock-key
  - Compromise between access lists and capability lists
  - Each object has list of unique bit patterns, called **locks**
  - Each domain as list of unique bit patterns called **keys**
  - Process in a domain can only access object if domain has key that matches one of the locks

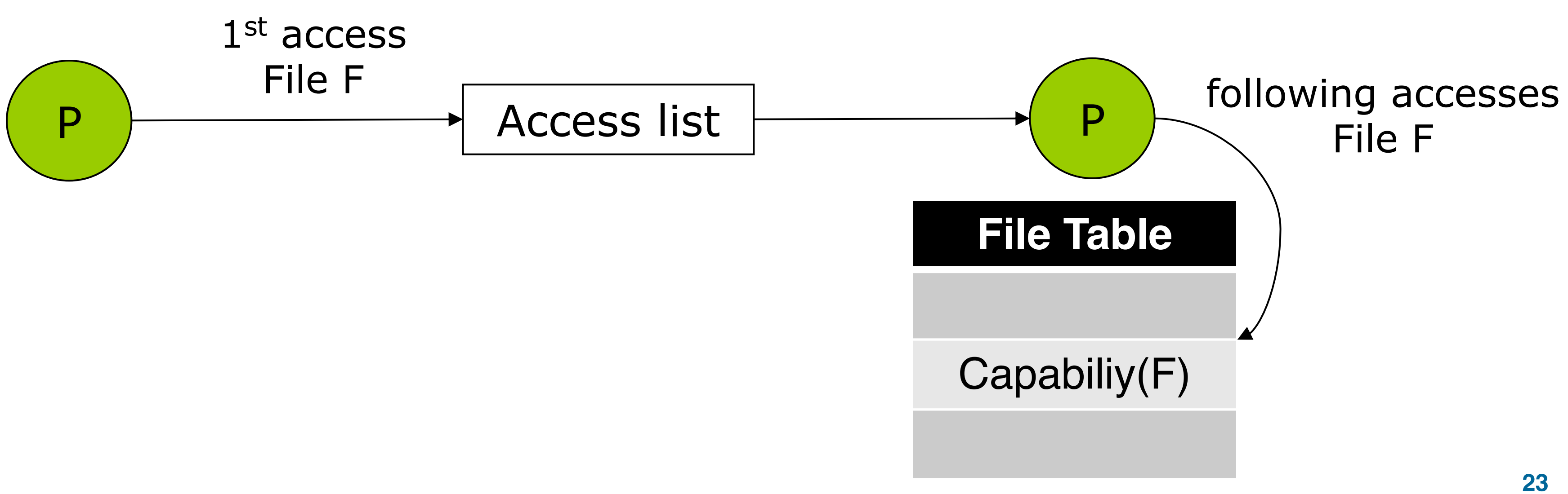


Comparison of Implementations

- Many trade-offs to consider
  - Global table is simple, but can be large
  - Access lists correspond to needs of users
    - Every access to an object must be checked
      - Many objects and access rights -> slow
  - Capability lists useful for localizing information for a given process
    - But *mass* revocation capabilities can be inefficient
  - Lock-key effective and flexible, keys can be passed freely from domain to domain, easy revocation (change a lock)

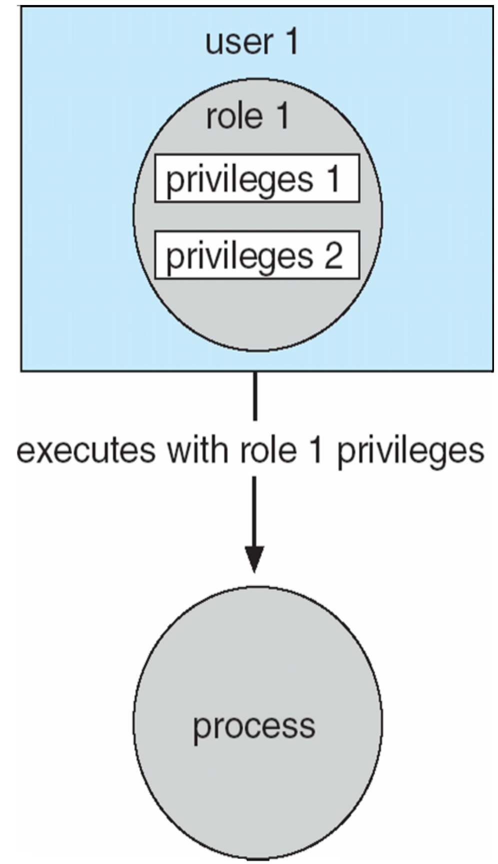
Comparison of Implementations (Cont.)

- Most systems use combination of access lists and capabilities
  - First access to an object -> access list searched
    - If allowed, capability created and attached to process
      - Additional accesses need not be checked
    - After last access, capability destroyed
    - Consider file system with ACLs per file



Access Control

- Protection can be applied to **non-file resources**
- Oracle Solaris 10 provides **role-based access control** (**RBAC**) to implement least privilege
  - ***Privilege*** is right to execute system call or use an option within a system call
  - Can be assigned to processes
  - Users assigned ***roles*** granting access to privileges and programs
    - Enable role via password to gain its privileges
  - Similar to access matrix



Revocation of Access Rights

- Various options to remove the access right of a domain to an object
  - **Immediate vs. delayed (when will it take place?)**
  - **Selective vs. general (all users or a subset?)**
  - **Partial vs. total (all access rights or a subset?)**
  - **Temporary vs. permanent**
- **Access List** – Delete access rights from access list
  - **Simple** – search access list and remove entry
  - **Immediate**, **general** or **selective**, **total** or **partial**, **permanent** or **temporary**

Revocation of Access Rights (Cont.)

- **Capability List** – Scheme required to **locate capability** in the system before capability can be revoked
  - **Reacquisition** – periodic delete, with require and denial if revoked
  - **Back-pointers** – set of pointers from each object to all capabilities of that object (Multics). Follow the pointers and change capabilities.
  - **Indirection** – capability points to global table entry which points to object – delete entry from global table, not selective (CAL)
  - **Keys** – unique bits associated with capability, generated when capability created
    - Master key associated with object, key matches master key for access
    - Revocation – create new master key
    - Policy decision of who can create and modify keys – object owner or others?

Language-Based Protection

- Specification of protection in a programming language allows the high-level description of policies for the allocation and use of resources
- Language implementation can provide software for protection enforcement when automatic hardware-supported checking is unavailable
- Interpret protection specifications to generate calls on whatever protection system is provided by the hardware and the operating system

Protection in Java 2

- Protection is handled by the Java Virtual Machine (JVM)
- A **class** is assigned a protection domain when it is loaded by the JVM
- The protection domain indicates what operations the class can (and cannot) perform
- If a library **method** is invoked that performs a privileged operation, the stack is **inspected** to ensure the operation can be performed by the library
- Generally, Java's load-time and run-time checks enforce **type safety**
- Classes effectively **encapsulate** and protect data and methods from other classes

Stack Inspection

protection domain:	untrusted applet	URL loader	networking
socket permission:	none	*.lucent.com:80, connect	any

class:	gui:
	. . .
	get(url);
	open(addr);
	. . .
		get(URL u):
		. . .
		doPrivileged {
		open(‘proxy.lucent.com:80’);
		}
		<request u from proxy>
		. . .
			open(Addr a):
			. . .
			checkPermission (a, connect);
			connect (a);
			. . .

End of Chapter 14