

# OPERATING SYSTEMS

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## I/O Management, System Protection and Security

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**System Protection – Implementation of Access Matrix, Access control, Access rights**

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## Slides Credits for all PPTs of this course

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- The slides/diagrams in this course are an **adaptation, combination,** and **enhancement** of material from the following resources and persons:
1. Slides of Operating System Concepts, Abraham Silberschatz, Peter Baer Galvin, Greg Gagne - 9<sup>th</sup> edition 2013 and some slides from 10<sup>th</sup> edition 2018
  2. Some conceptual text and diagram from Operating Systems - Internals and Design Principles, William Stallings, 9<sup>th</sup> edition 2018
  3. Some presentation transcripts from A. Frank – P. Weisberg
  4. Some conceptual text from Operating Systems: Three Easy Pieces, Remzi Arpaci-Dusseau, Andrea Arpaci Dusseau

- Generally, a sparse matrix (i.e. most of the entries will be empty)
- **Option 1 – Global table**
  - Store ordered triples **<domain, object, rights-set>** in table
  - A requested operation  $M$  on object  $O_j$  within domain  $D_i$   $\rightarrow$  search table for a triple  $\langle D_i, O_j, R_k \rangle$ 
    - 4 with  $M \in R_k$
    - 4 If triple found, operation is allowed to continue; otherwise an exception or condition is raised
  - But table could be large  $\rightarrow$  won't fit in main memory
    - Virtual memory techniques can be used for managing this table
  - Difficult to group objects
    - consider an object that all domains can read, this object must have a separate entry in every domain)

- **Option 2 – Access lists for objects**
  - Each **column** implemented as an access list for one object i.e. specifying user names and the types of access allowed for each user (empty entries can be discarded)
  - 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  $M \in$  default set, also allow access
    - For efficiency, check the default set first and then search the access list

- Each column = Access-control list for one object  
Defines who can perform what operation  
  
Domain 1 = Read, Write  
Domain 2 = Read  
Domain 3 = Read
- Each Row = Capability List (like a key)  
For each domain, what operations allowed on what objects  
Object F1 – Read  
Object F4 – Read, Write, Execute  
Object F5 – Read, Write, Delete, Copy

- **Option 3 – Capability list for domains**

- Instead of object-based (i.e column wise), list is domain based (i.e row wise)
- **Capability list** for domain is list of objects together with operations allowed 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
  - 4 **Possession of capability** means access is allowed
- Capability list associated with domain but never directly accessible to a process executing in that domain
  - 4 Rather, protected object, maintained by OS and accessed by the user indirectly
  - 4 Like a “secure pointer”
  - 4 Idea can be extended up to the application level

- **Option 4 – Lock-key**

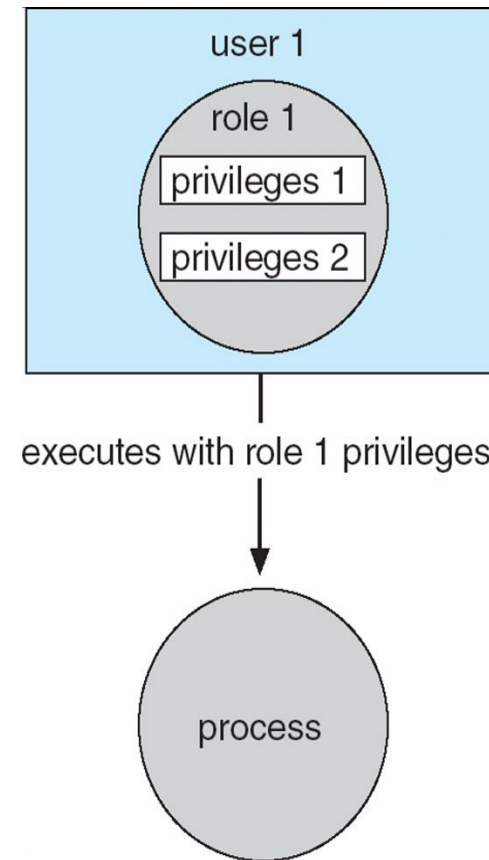
- Compromise between access lists and capability lists
- Each object has a list of unique bit patterns, called **locks**
- Each domain has a list of unique bit patterns called **keys** (managed by the OS)
- Process in a domain can only access object if domain has a key that matches one of the locks



- Many trade-offs to consider
  - Global table is simple, but can be large
  - Access lists correspond to needs of users
    - 4 Access rights for a particular domain is non-localized, so difficult to determine the set of access rights for each domain
    - 4 Every access to an object must be checked
      - Many objects and access rights -> slow (i.e not suitable for large system with long access lists)
  - Capability lists useful for localizing information for a given process
    - 4 But revocation capabilities can be inefficient
  - Lock-key effective and flexible, keys can be passed freely from domain to domain, easy revocation

- Most systems use combination of access lists and capabilities
  - First access to an object -> access list searched
    - 4 If allowed, capability created and attached to process
      - Additional accesses need not be checked
    - 4 After last access, capability destroyed
    - 4 Consider file system with ACLs per file recorded in a new entry in a file table (file table maintained by the OS such as UNIX and protection is ensured)

- 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 (ex: write access for a file) within a system call
  - Can be assigned to processes
  - Users assigned **roles** granting access to privileges and programs
    - 4 Enable role via password to gain its privileges
  - Similar to access matrix



- Various options to remove the access right of a domain to an object
  - **Immediate vs. delayed** (i.e. when revocation will occur)
  - **Selective vs. general** (i.e. select group of users or all the users)
  - **Partial vs. total** (i.e. subset of the rights or all the rights)
  - **Temporary vs. permanent** (can access right be revoked and obtained later?)
- **Access List** – Delete access rights from access list
  - **Simple** – search access list and remove entry, revocation is easy
  - **Immediate, general or selective, total or partial, permanent or temporary**

- **Capability List** – Scheme required to locate capability in the system before capability can be revoked
  - **Reacquisition** – periodic delete from each domain, with reacquire and denial if revoked by a process
  - **Back-pointers** – set of pointers from each object to all capabilities of that object, follow these pointers for revocation (adopted in Multics)
  - **Indirection** – capability points to global table entry which in turn points to object – delete entry from global table, selective revocation not allowed
  - **Keys** – unique bit pattern associated with a capability, generated when capability is created
    - 4 Master key associated with object, key matches master key for access
    - 4 Revocation – create new master key (with a new value)
    - 4 Policy decision of who can create and modify keys – object owner or others?



**THANK YOU**

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