Lecture 15: Capabilities

CS 181S

November 5, 2018

Where we were…

- **Authentication:** mechanisms that bind principals to actions

- **Authorization:** mechanisms that govern whether actions are permitted
  - Discretionary Access Control
  - Mandatory Access Control

Access Control Policy

- An **access control policy** specifies which of the **operations** associated with any given **object** each **principal** is authorized to perform
- Expressed as a relation $Auth$:

$Auth$		Objects	
		dac.tex	dac.pptx
principals	ebirrell	r,w	r,w
	faculty	r	r
	student		r

Capability Lists

Access Control Lists

Capability Lists

- The capability list for a principal P is a list

$$\langle O_1, Privs_1\rangle, \langle O_2, Privs_2\rangle, \dots, \langle O_n, Privs_n\rangle$$

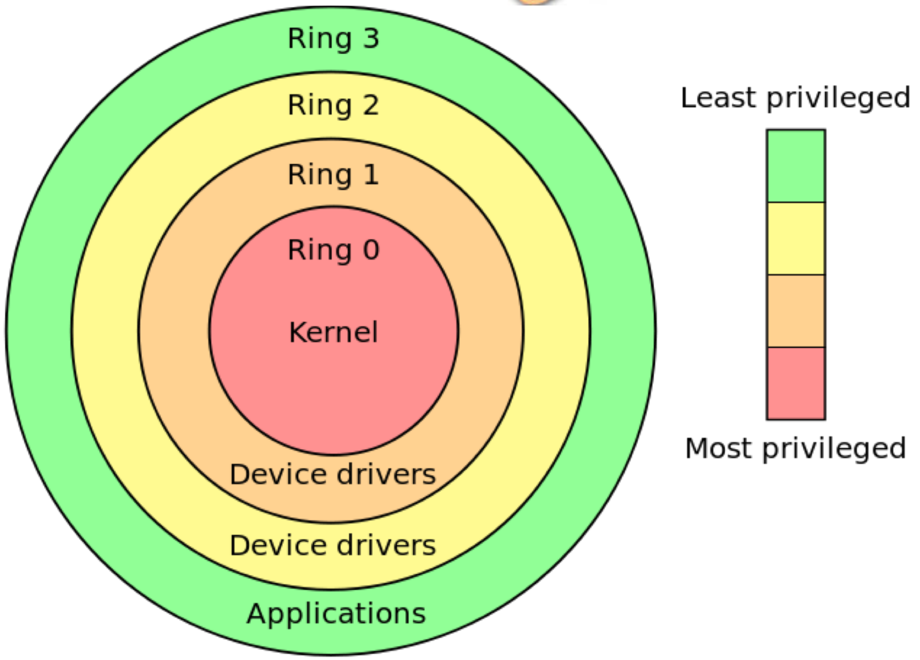
  - e.g., ⟨dac.tex, {r,w}⟩ ⟨dac.pptx, {r,w}⟩
- **Capabilities** carry privileges.
  1) **Authorization:** Performing operation op on object O_i requires a principal P to hold a capability $C_i = \langle O_i, Privs_i\rangle$ such that $op \in Privs_i$
  2) **Unforgeability:** Capabilities cannot be counterfeited or corrupted.
- Note: Capabilities are (typically) transferable

Capabilities

- Advantages:
  - Natural approach for user-defined objects
  - Eliminates confused deputy problems
- Disadvantages:
  - Review of permissions?
  - Revocation?
  - Delegation?
  - Privacy?

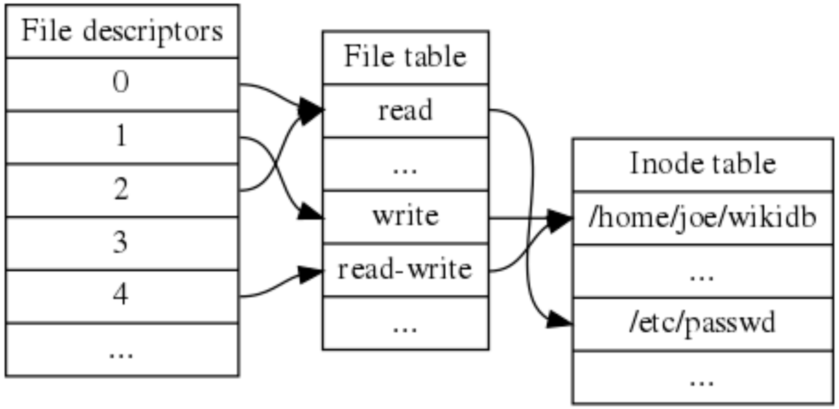
C-Lists

- OS maintains and stores stores list of capabilities $C_i = \langle O_i, Privs_i \rangle$ for each principal (process)
  1) **Authorization:** OS mediates access to objects, checks process capabilities
  2) **Unforgeability:** capabilities are stored in protected memory region (kernel memory)



Example: File Descriptor Table

- In Unix etc, a file descriptor is a handle used to reference files and I/O resources
- File descriptors have modes (read, write) and are stored in per-process file descriptor table
- File descriptors can be passed between processes using sendmsg()

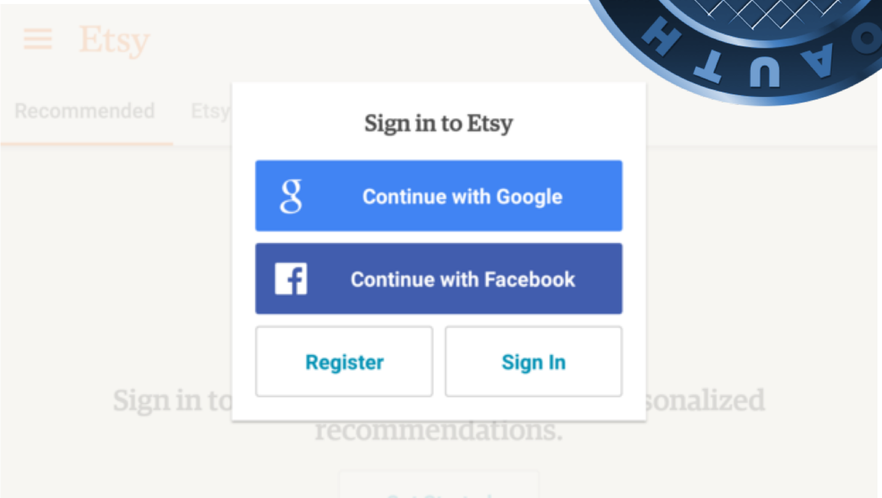


Example: Google Fuchsia

- new OS in development by Google
- possibly intended as a universal across-platform OS for the IoT era (lots of speculation)
- capability-based microkernel embraces capabilities (handles) for all kernel objects
  - socket, port, virtual memory region, process, thread, etc.

Example: OAuth2

- Industry standard authorization protocol
- Used for single sign-on by major IDPs
  - Facebook, Google
- A **bearer token** contains a unique identifier



Cryptographically-protected capabilities

- Object owner creates capabilities using a digital signature scheme
- Capabilities are triples $C = \langle O, Privs, \mathrm{Sig}(O, Privs; k_O)\rangle$
- **Authorization:** P is permitted to perform op on O if P produces a capability for O with $op \in Privs$ and a valid signature
- **Unforgeability:** digital signatures are unforgeable to adversaries who don't know private key k_O

- Note: assumes PKI

Restricted Delegation

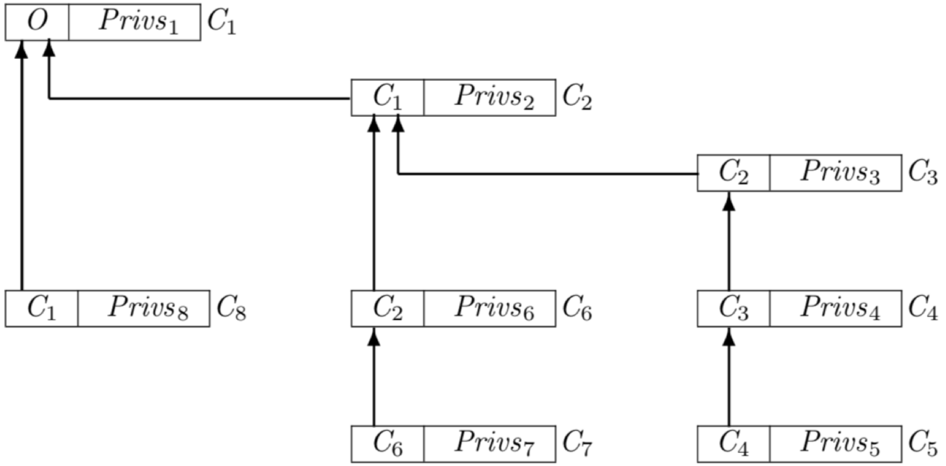
- $C_0 = \langle O, Privs_0, k_1, s_0 \rangle$
  - where $s_0 = \text{Sig}(O, Privs_0, k_1; k_0)$
- $C_1 = \langle O, Privs_1, k_2, d_0, s_1 \rangle$
  - Where $d_0 = \text{Sig}(O, Privs_0, k_1; k_0)$ and $s_1 = \text{Sig}(O, Privs_1, k_2, d_0; k_1)$
- $C_2 = \langle O, Privs_2, k_3, d_0, d_1, s_2 \rangle$
  - Where $d_1 = \text{Sig}(O, Privs_1, k_2; k_1)$ and $s_2 = \text{Sig}(O, Privs_2, k_3, d_0, d_1; k_2)$

- $C_n = \langle O, Privs_n, k_{n+1}, d_0, \ldots, d_{n-1}, s_n \rangle$
  - Where $d_i = \text{Sig}(O, Privs_i, k_{i+1}; k_i)$

    $s_i = \text{Sig}(O, Privs_i, k_{i+1}, s_0, \ldots s_{i-1}; k_i)$

Revocation

- Revocation Tags
  - Capabilities are tuples $C = \langle O, Privs, rt_c, \mathrm{Sig}(O, Privs, rt_c; k)\rangle$
  - Access to object O is guarded by a reference monitor; monitor maintains a list of revoked tags rt_c
- Capability Chains
  - Objects can be other capabilities!
  - P is authorized to perform op on O if P holds a capability C_i and $op \in Privs_k$ holds for every capability C_k in the chain from C_i to C_1

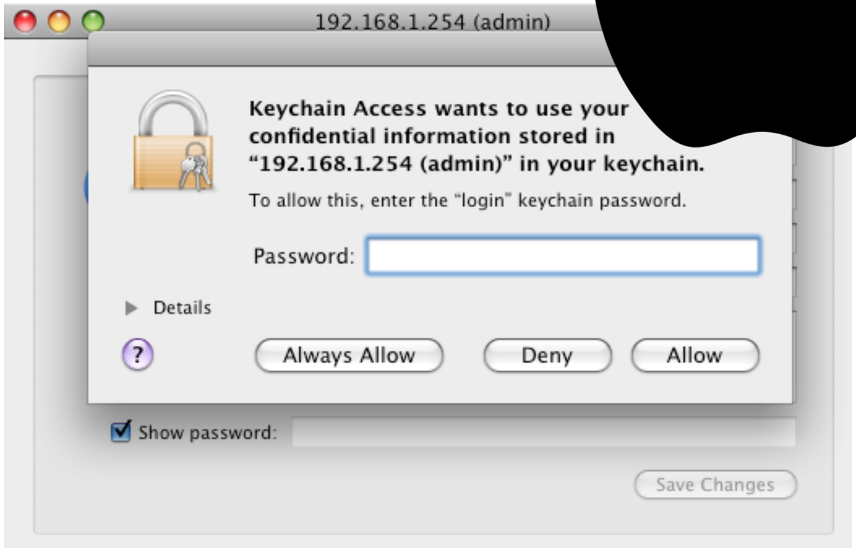


Keys as capabilities

- Encrypt object
- Decryption method functions as reference monitor:
  - **Authorization:** correct key will decrypt object -> allow access
  - **Unforgeability:** incorrect key will not decrypt
- Note: no notion of separate privileges

Example: Mac keychains

- OSX/iOS password manager
- uses password-based encryption (AES-256) to store username/password credentials
- supports multiple keychains

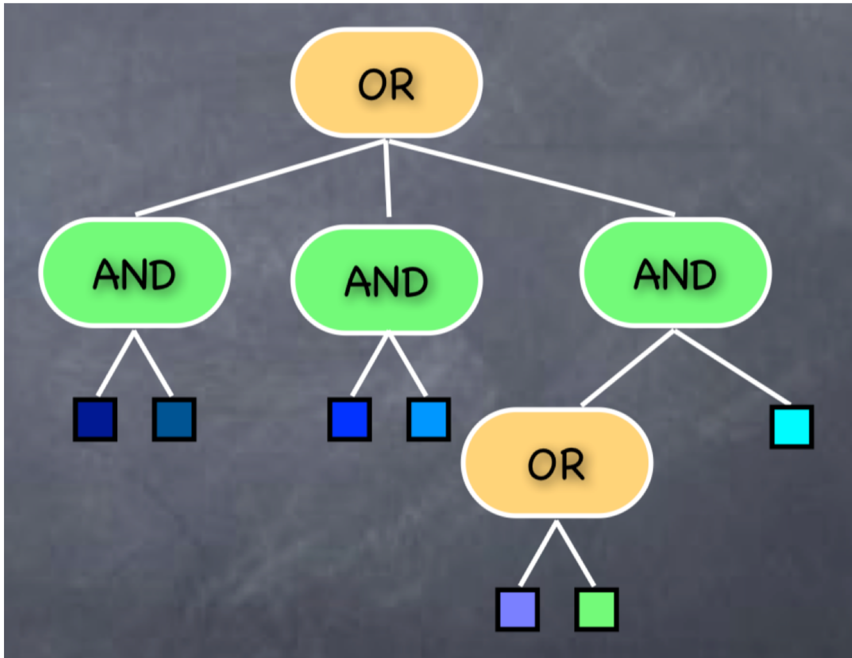


Example: CryptDB

- Encrypted database system. Inspiration for several application-grade encrypted database systems
- Processes database queries on encrypted data
- Uses chains of keys (starting with user password) to decrypt values/authorize users
    - onion encryption

Attribute-based encryption

- Type of public-key encryption in which secret keys depend on user attributes
- Users can only decrypt a ciphertext if they hold a key for appropriate attributes
- A KDC creates secret keys for users based on attributes



What about privacy?