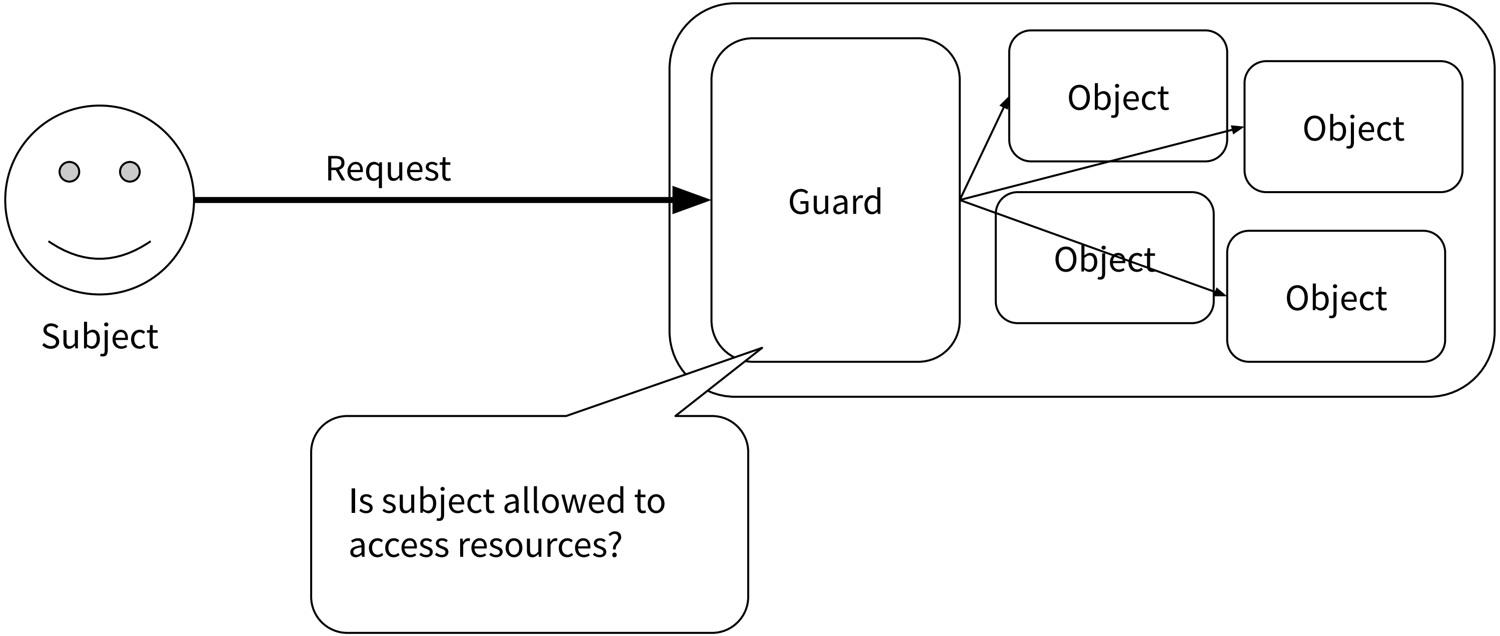
Capabilities

COS 316: Principles of Computer System Design

Amit Levy & Wyatt Lloyd

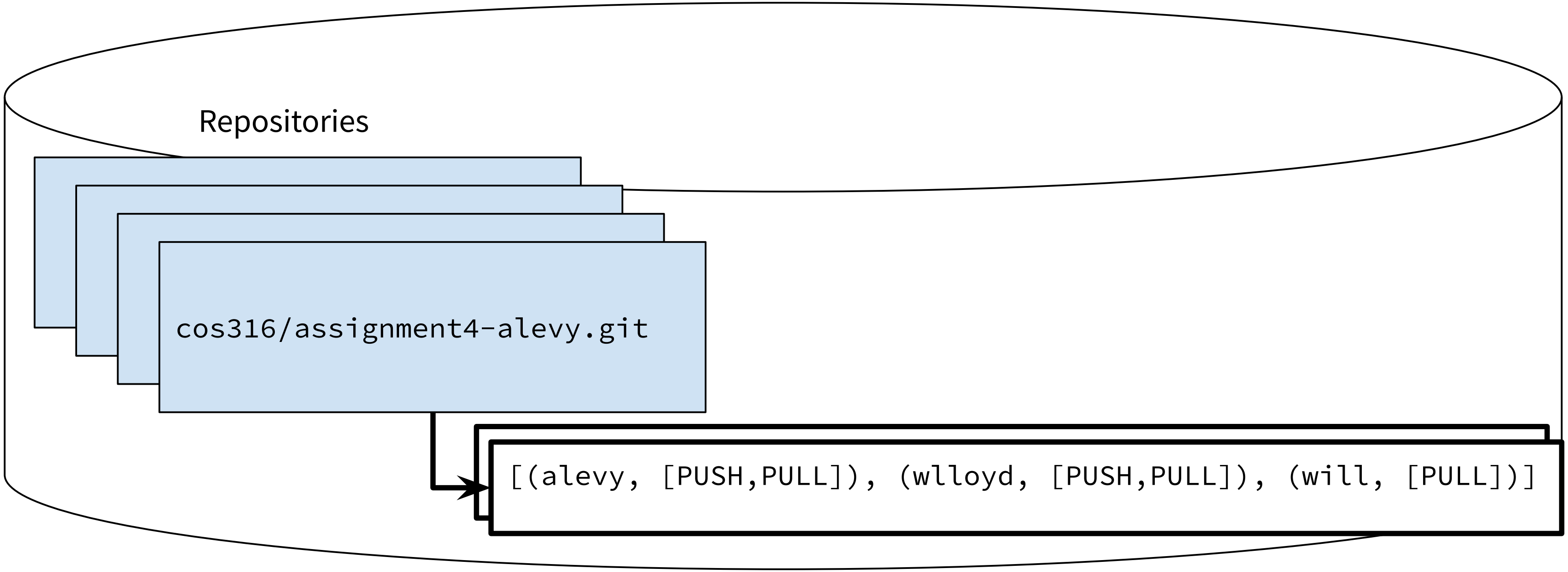
Last Time - The Guard Model



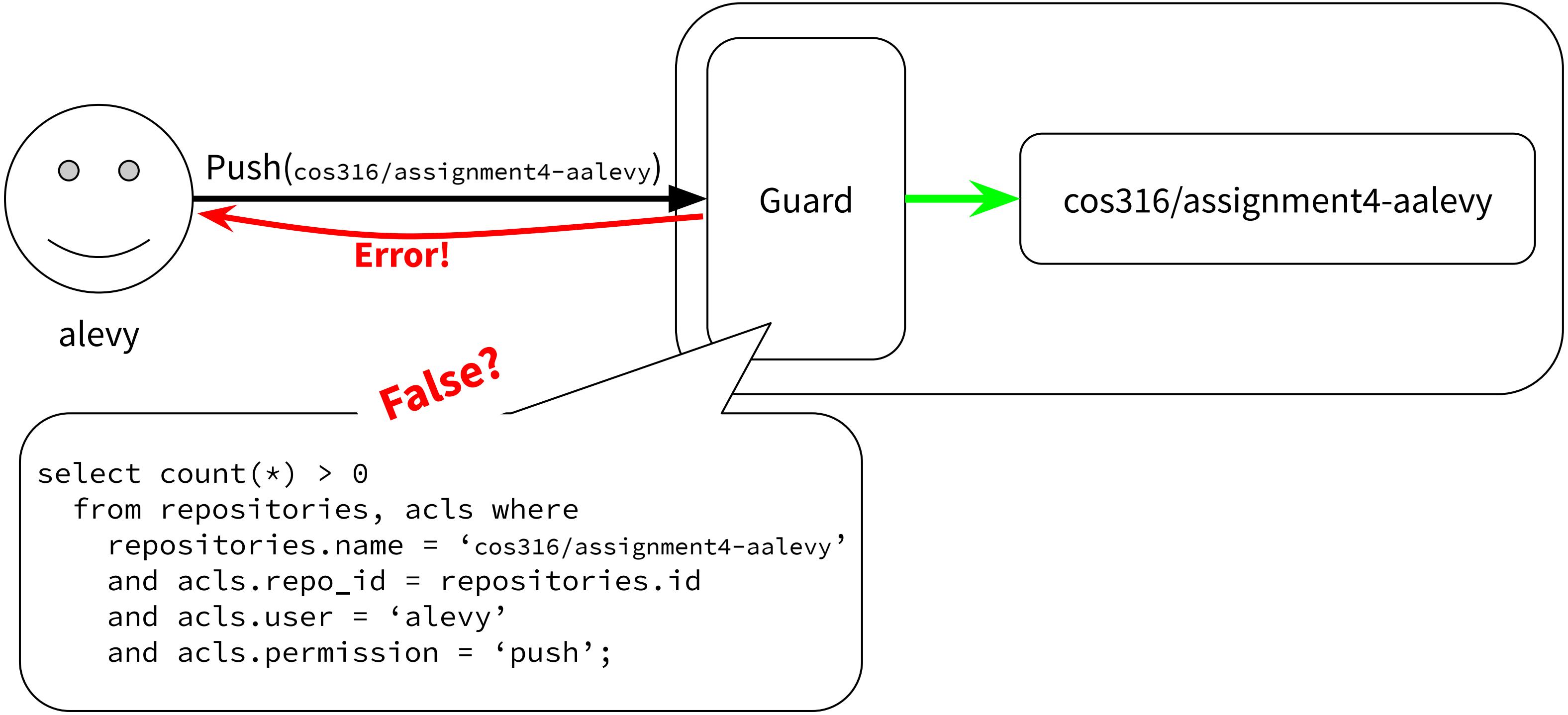
Is subject allowed to access resources?

Last Time - Access Control Lists

Associate a list of (user, permissions) with each resource


Repositories
cos316/assignment4-alevy.git
[(alevy, [PUSH,PULL]), (wlloyd, [PUSH,PULL]), (will, [PULL])]

Last Time - ACLs in Action



```
select count(*) > 0
  from repositories, acls where
    repositories.name = ‘cos316/assignment4-aalevy’
    and acls.repo_id = repositories.id
    and acls.user = ‘alevy’
    and acls.permission = ‘push’;
```

Last Time - Access Control Lists

Advantages

- Simple to implement
- Simple to administer
- Easy to revoke access

Drawbacks

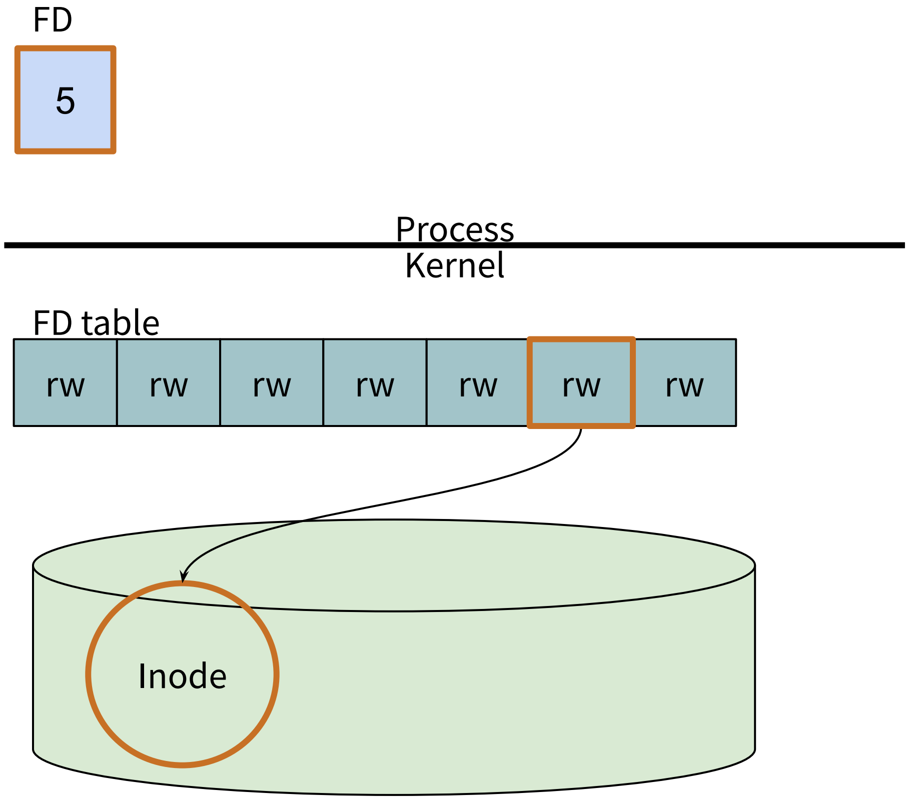
- Tradeoff granularity for simplicity
  - More granular permissions require more complex rules in the guard
- Doesn’t scale well
  - E.g. need up to Users X Repos X Access Right entries in ACL table
- Centralized access control
  - Needs server’s cooperation to delegate access

An Alternative - Capabilities

“[A] token, ticket, or key that gives the possessor permission to access an entity or object in a computer system.” - *Capability-Based Computer Systems*

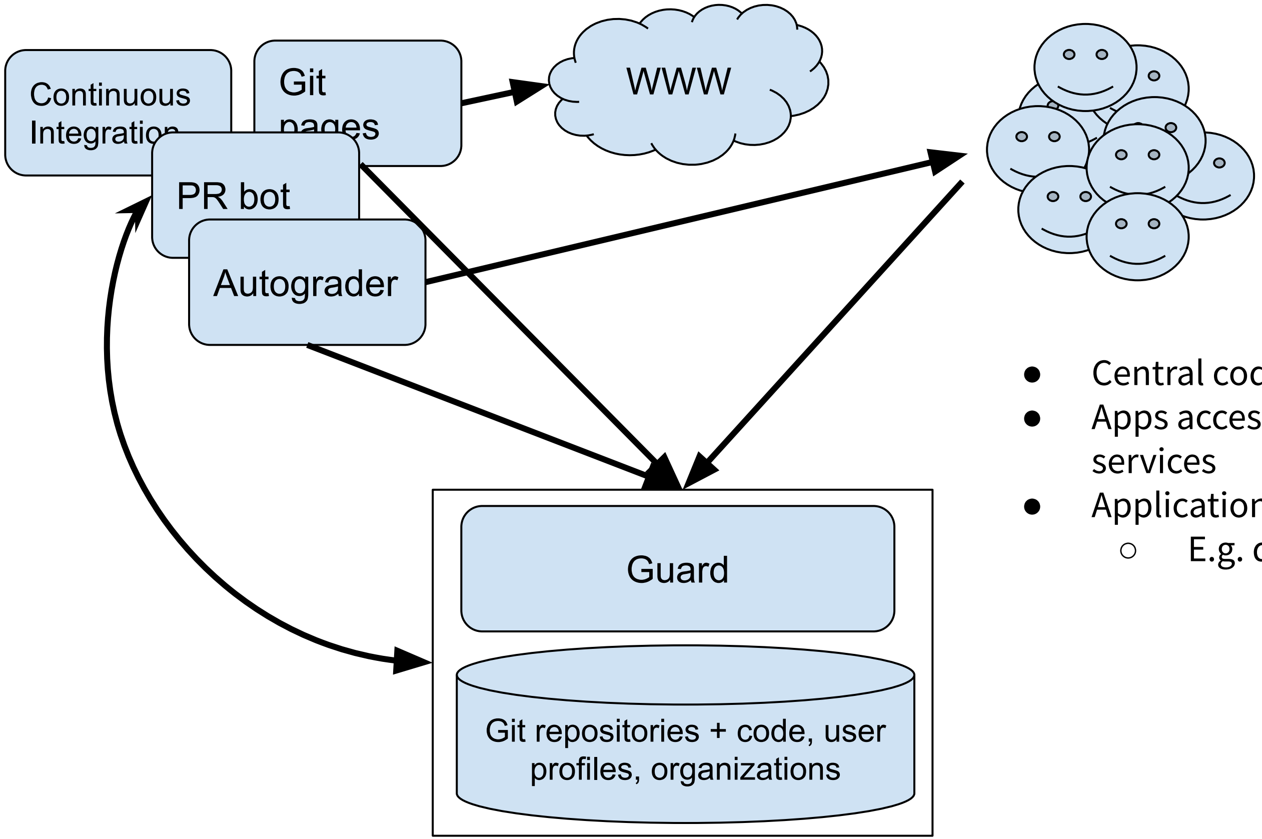
- Self-describing
  - Contains both object name and permitted operations
- Globally meaningful
  - Object and operation names are not subject-specific
- Transferrable
  - A subject can pass a capability to another (e.g. a sub-process, via IPC, a third-party app, etc)
  - Ideally can delegate subset of capabilities
- Unforgeable
  - Subjects cannot create capabilities with arbitrary permissions

File Descriptors as Proto-Capabilities



- Unforgeable ✓
  - Process-level fd is just an index in a kernel structure
- Self-describing ✓
  - Kernel fd contains reference to inode + permissions
- Globally meaningful ✗
  - Fds are process-specific
- Transferrable ✓/ ✗
  - Via IPC sendmsg/recvmsg

Consider a GitHub-like Ecosystem



- Central code DB
- Apps access DB resources to provide extra services
- Application access must be restricted:
    - E.g. don’t make private repos public

User Permissions using Capabilities

Hand out communicable, unforgeable tokens encoding:

- Object
- Access right

Users store capabilities, not the database

E.g.

“**`push(cos316/assignment4-aalevy)`**”

“**`pull(cos316/assignment4-aalevy)`**”

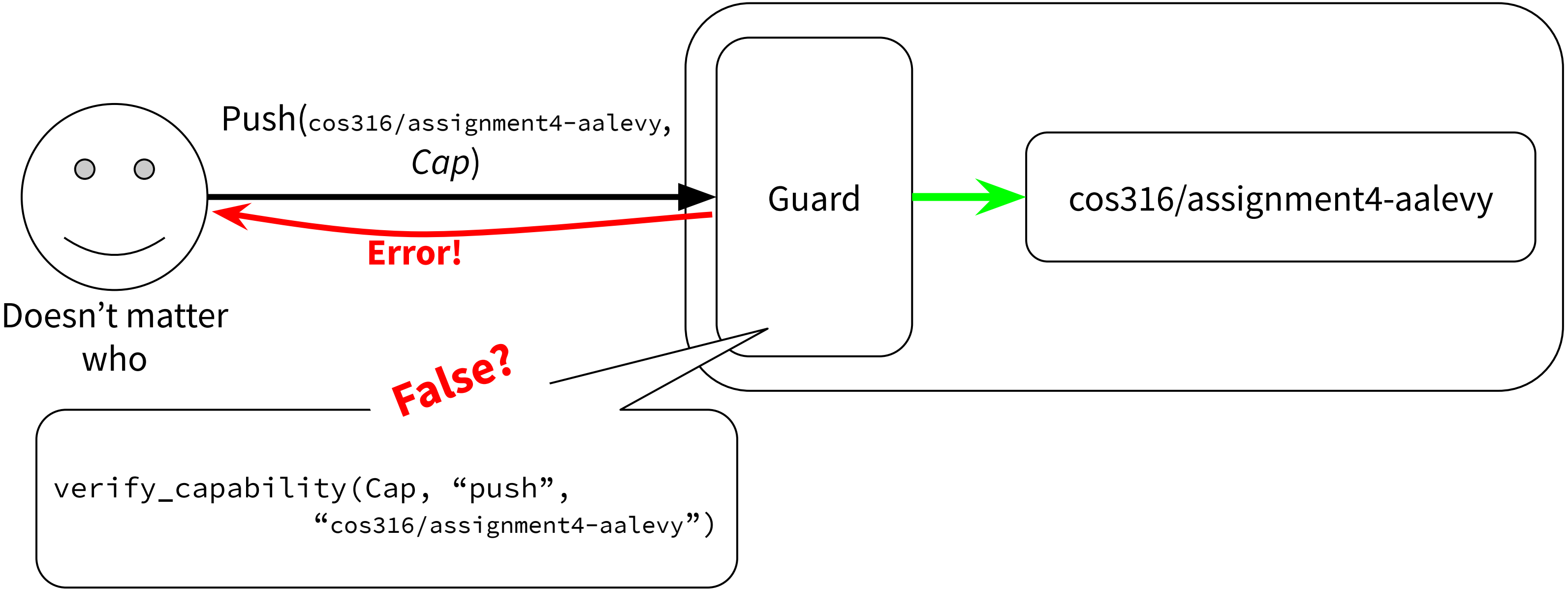
Implementing Capabilities with HMAC

HMAC - a keyed-hash function: `hmac(secret_key, data) hash of data`

```
fn gen_capability(op, repo) {
  hmac(db_secret, fmt.Sprintf(“%s(%s)”, op, repo))
}

fn verify_capability(cap, op, repo) {
  cap == hmac(db_secret, fmt.Sprintf(“%s(%s)”, op, repo))
}
```

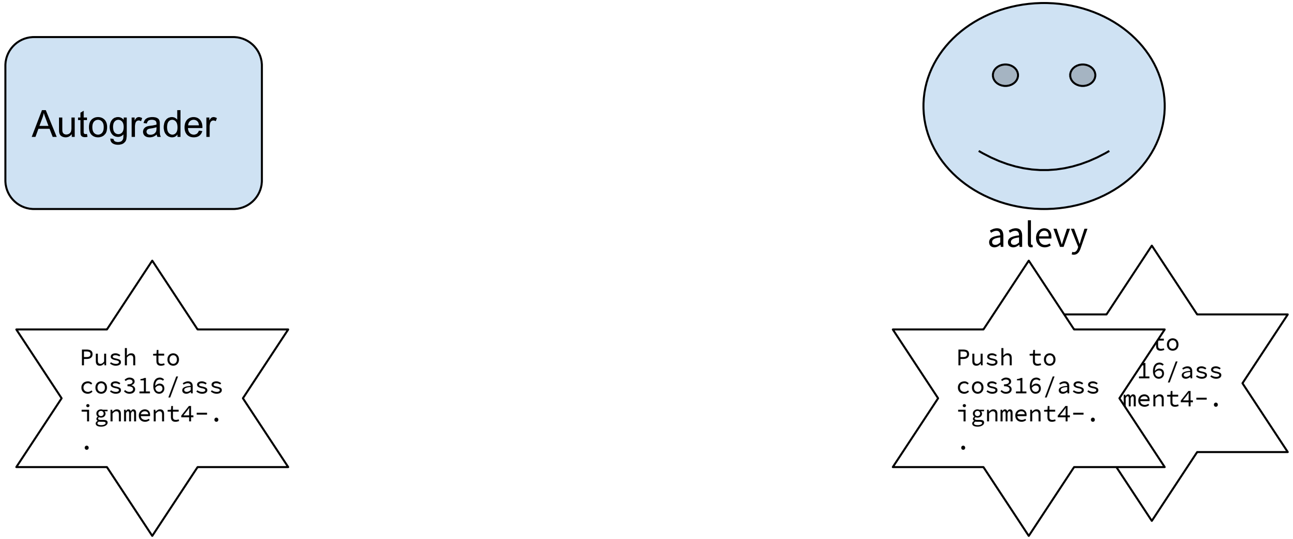
Capabilities in Action


Push(cos316/assignment4-aalevy, *Cap*)
Error!
Doesn't matter who
Guard
cos316/assignment4-aalevy
False?

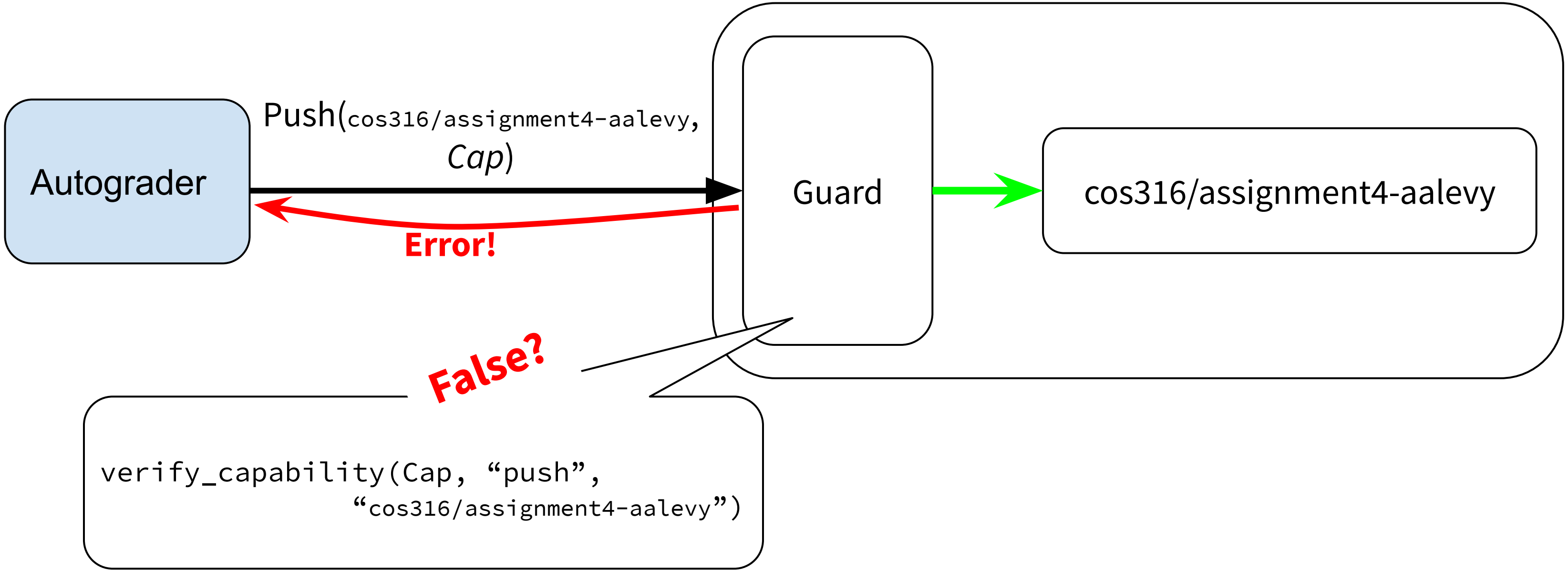
```
verify_capability(Cap, “push”,
                 “cos316/assignment4-aalevy”)
```

Extending Capabilities to Applications

- Users can simply give applications a subset of their capabilities



Extending Capabilities to Applications


Autograder
Push(cos316/assignment4-aalevy, *Cap*)
Error!
Guard
cos316/assignment4-aalevy
False?

```
verify_capability(Cap, “push”,
              “cos316/assignment4-aalevy”)
```

Capabilities

Advantages

- Decentralized access control
  - Anyone can “pass” anyone a capability
- Scales well
- Granular permissions are simple to check

Drawbacks

- How do you revoke a capability?
- Moves complexity to users/clients
  - Users have to manage their capabilities now

Capabilities In The Wild

- Operating Systems
  - History of industry and research operating systems
    -
  - FreeBSD’s Capsicum
  - Fuschia OS
- Web
  - S3 Signed URLs
    - URL to private resources, contain signature, expiration, permitted HTTP methods, etc
  - CDN-hosted images/videos (FB, Instagram, YouTube)
    - Browsing via Web page/app is protected by login+cookie, but media typically fetched unauthenticated

Next time...

We still have a problem!

The autograder is allowed to:

- read all cos316/ repositories
- comment on all cos316/ repositories

Can code from a private repository end up in a comment on a public repository?