ECE391
Computer System Engineering

Lecture 26

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Lecture Topics

- Driver design process
- I-mail design

I-mail and Device Driver Design

- Example is Illinois mail (*I-mail*)
  - instant messaging within the Linux kernel
  - (perhaps not a best idea) but good example
    - somewhat complex abstraction
    - issues similar to other communication drivers (e.g., TCP/IP)
    - simpler than most real implementations
    - can be described from ground up

- **Course Notes 6a on the class web site**

Driver Design Process

0. “contemplate” security (hard/impossible to add in correctly as afterthought!)
1. write out all ops (in terms of visible interface)
2. design data structures
3. pick a locking strategy
4. determine locks needed, pick lock ordering
5. consider blocking issues & wakeup

Driver Design Process

6. consider dynamic allocation issues & hazards
7. write code
8. write subfunctions and synchronization rules
9. return to 3 or 4 if 7 or 8 fails
10. unit test

I-mail Design – Security

- Could just use the sysadmin for admin functions
- Instead, have I-mail administrator as a user with privileges
  - allows sysadmin to hand off I-mail rights
  - without giving away other rights

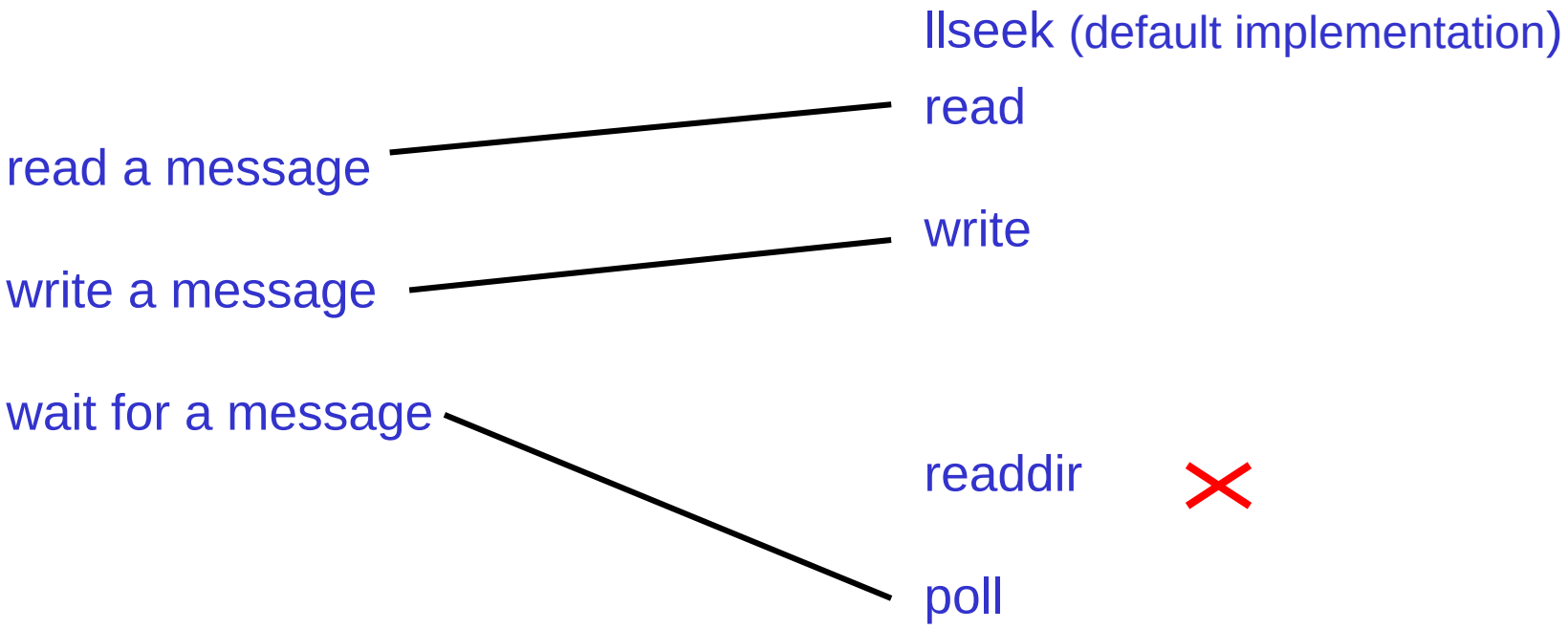
File Operations Structure

include/linux/fs.h

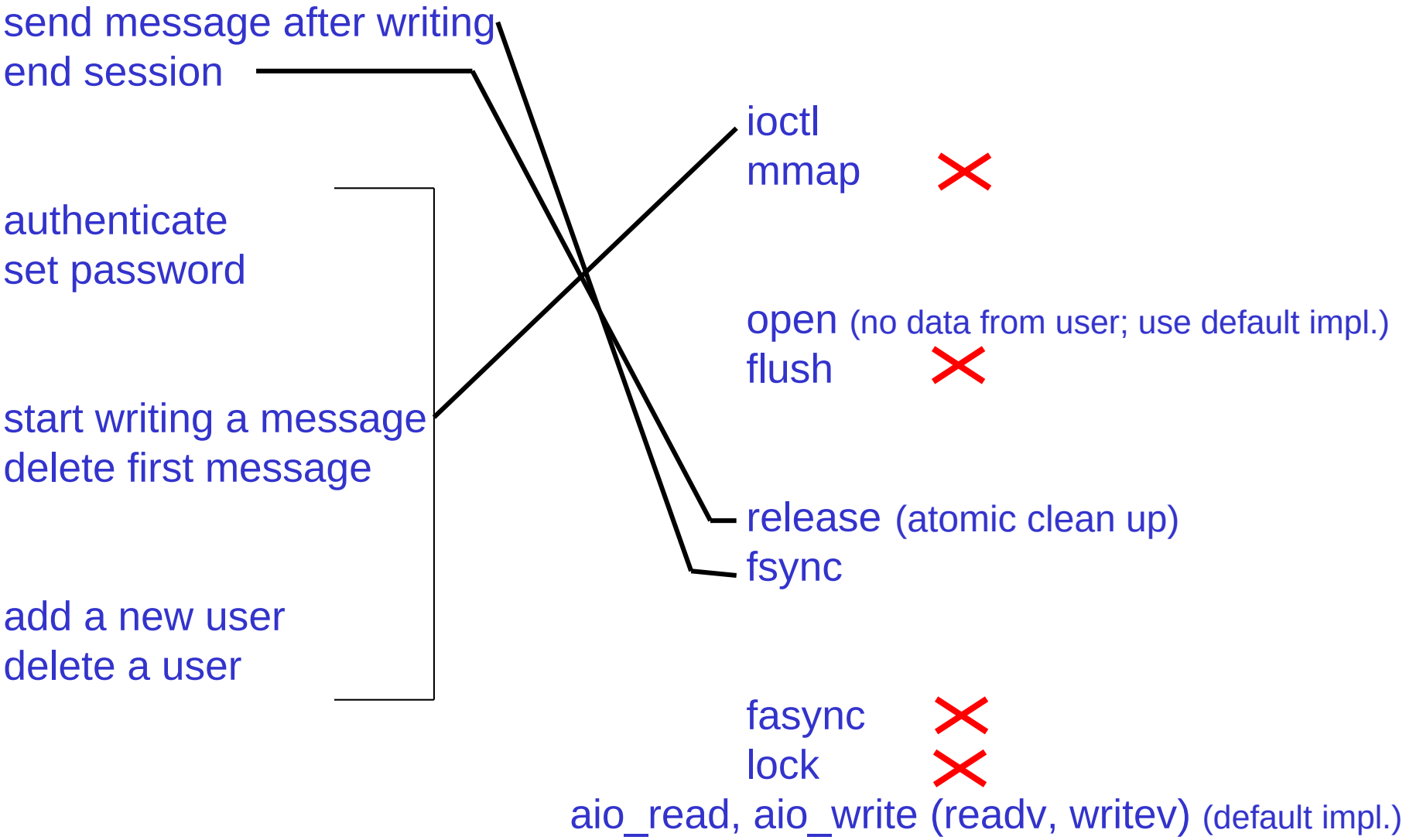
```
struct file_operations {
        struct module *owner;
        loff_t (*llseek) (struct file *, loff_t, int);
        ssize_t (*read) (struct file *, char __user *, size_t, loff_t *);
        ssize_t (*write) (struct file *, const char __user *, size_t, loff_t *);
        ssize_t (*aio_read) (struct kiocb *, const struct iovec *, unsigned long, loff_t);
        ssize_t (*aio_write) (struct kiocb *, const struct iovec *, unsigned long, loff_t);
        int (*readdir) (struct file *, void *, filldir_t);
        unsigned int (*poll) (struct file *, struct poll_table_struct *);
        int (*ioctl) (struct inode *, struct file *, unsigned int, unsigned long);
        long (*unlocked_ioctl) (struct file *, unsigned int, unsigned long);
        long (*compat_ioctl) (struct file *, unsigned int, unsigned long);
        int (*mmap) (struct file *, struct vm_area_struct *);
        int (*open) (struct inode *, struct file *);
        int (*flush) (struct file *, fl_owner_t id);
        int (*release) (struct inode *, struct file *);
        int (*fsync) (struct file *, struct dentry *, int datasync);
        int (*aio_fsync) (struct kiocb *, int datasync);
        int (*fasync) (int, struct file *, int);
        int (*lock) (struct file *, int, struct file_lock *);

        /* ... plus a couple more rarely used functions */
};
```

I-mail Design – Operations

- I-mail operations (and the system calls we'll use to execute them)



I-mail Design – Operations



I-mail Design – Operations by Entry Point

- Abstractly, a user has
  - authentication data
  - an association with a program (one file at a time)
  - a list of messages (reads only the first)
  - possibly a message being written

I-mail Design – Operations by Entry Point

- *read message* (read)
  - get data from first message in user's list
  - block until message arrives if necessary

- *write message* (write)
  - write data into message being written

I-mail Design – Operations by Entry Point

- *wait for message* (poll)
  - check status of message list (empty/not empty)
  - block until message arrives if necessary
- *end session* (release)
  - send the message being written
  - remove file association from user data
- *send message* (fsync)
  - send the message being written

I-mail Design – ioctl Operations

- authenticate
  - associate file with user data
- set password
  - change authentication data
- start write message
  - send the message being written
  - start writing a new message

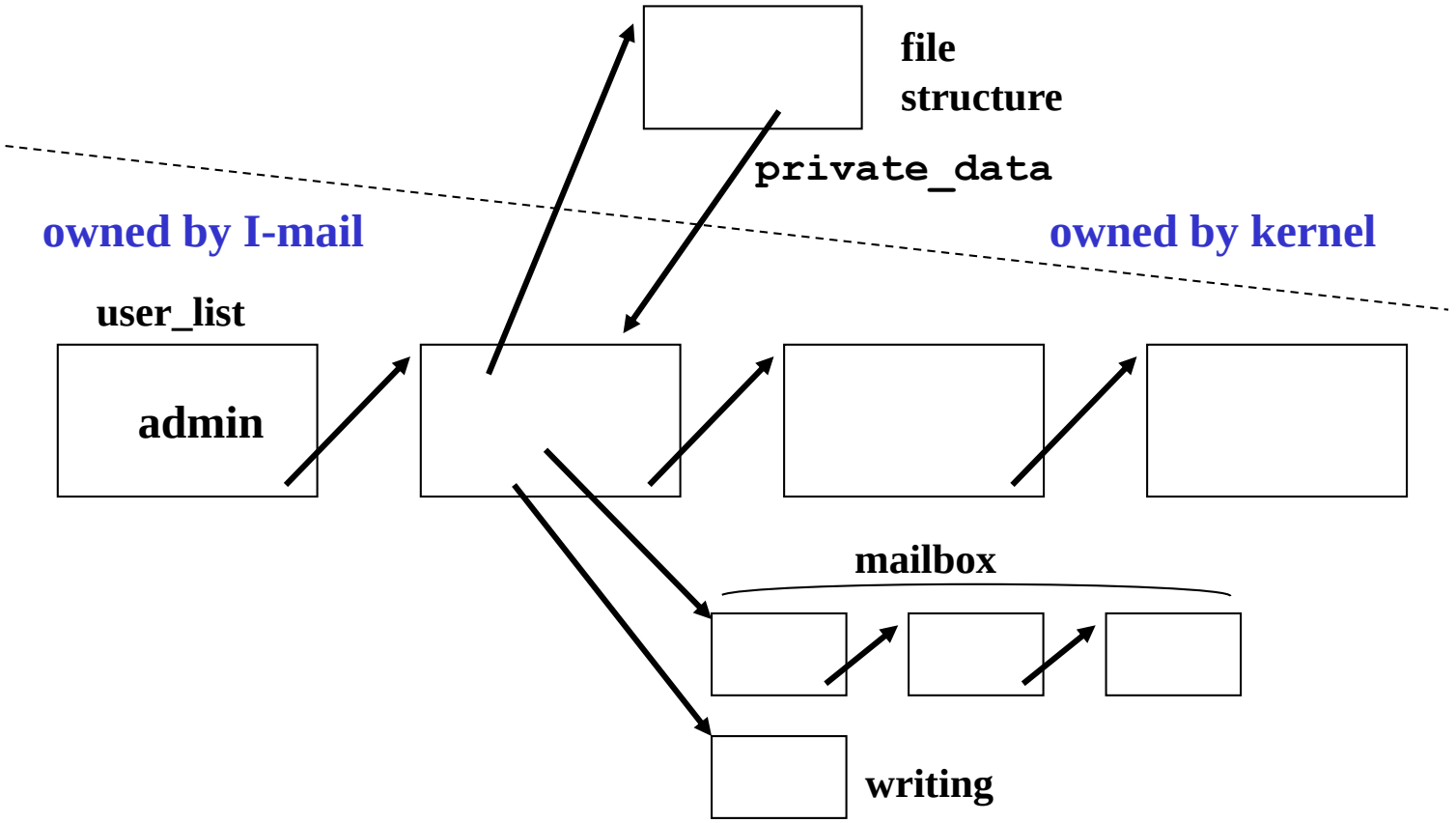
I-mail Design – ioctl Operations

- delete message
  - remove first message in list
  - reset file position
- add new user
  - check for a name conflict
  - create the new user
- delete user
  - kick off active user
  - delete messages and user

I-mail – Data Structures

- We want a user-level admin rather than requiring machine *sysadmin* privileges
- admin can’t be deleted
- make it the head of the user list

I-mail – Data Structures

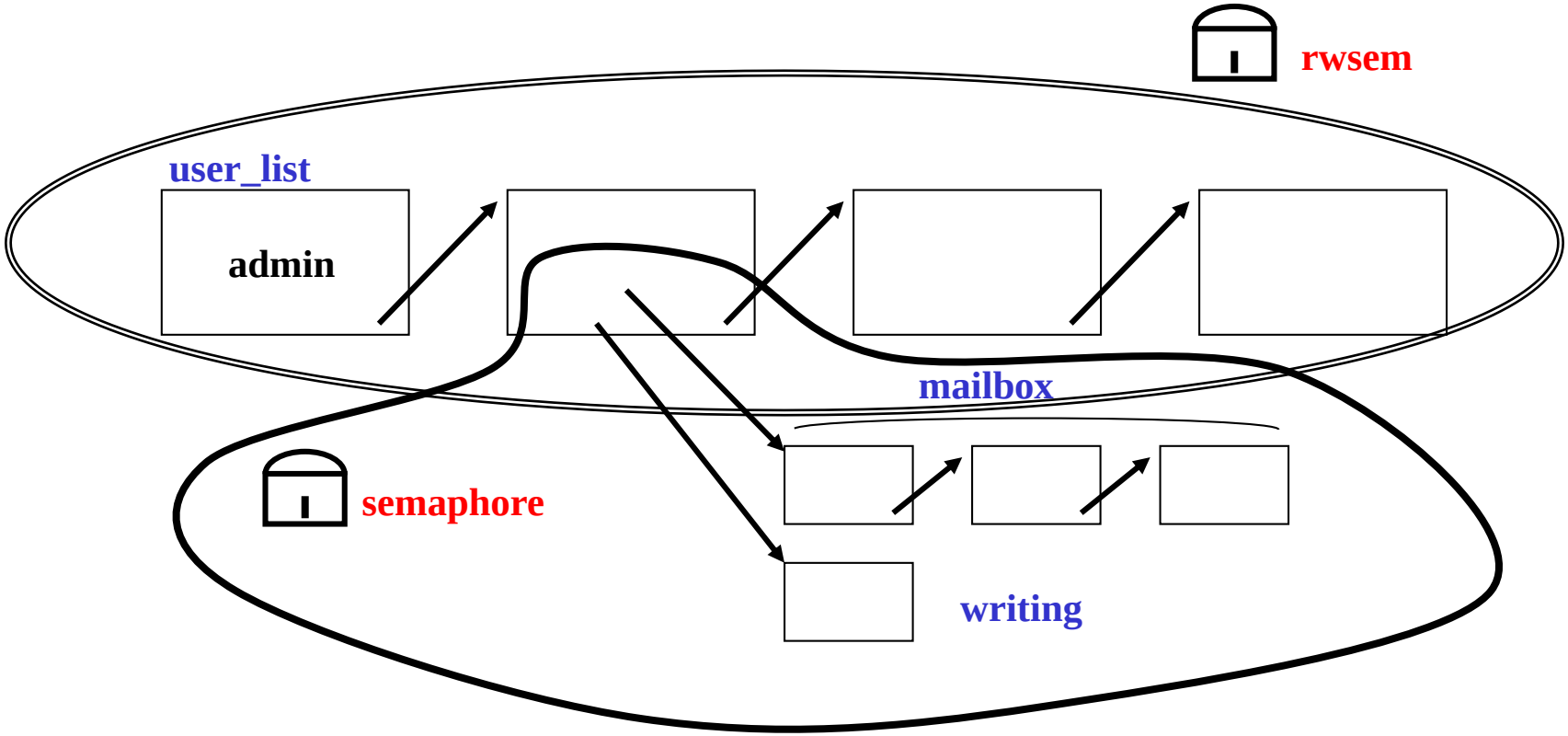


I-mail – locks

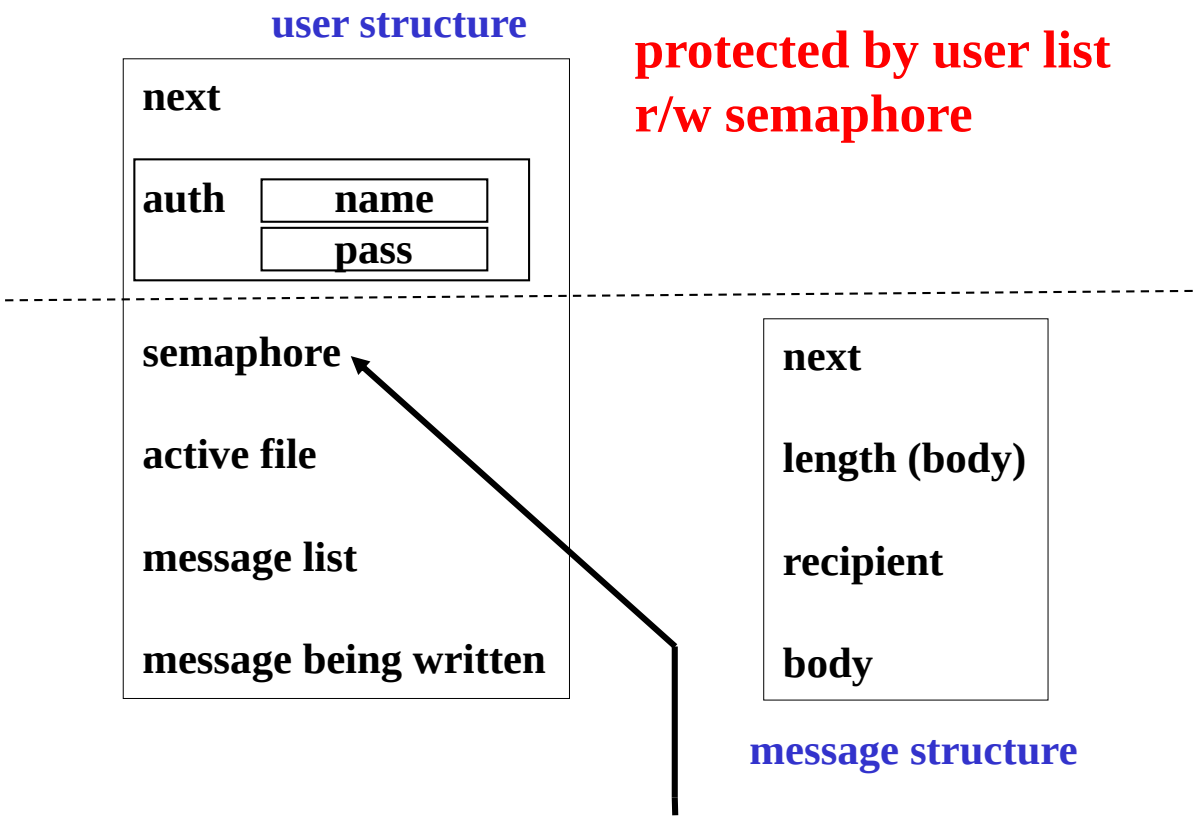
- For the user list
  - lots of reads, few writes
  - want concurrent authorization and management
  - use a reader/writer semaphore (rwsem)

- For the users
  - lots of reads and writes
  - typically by one user process
  - use a semaphore

I-mail – locks



I-mail – Data Structures with Lock Annotations



I-mail – Lock Order

- I-mail lock order
  1. user list r/w semaphore
  2. user data semaphore

– Q: Can you acquire >1 user semaphore simultaneously?
  – A: Absolutely not!
– Example: When delivering a message, at some point will need access to both user data structures; simply cannot hold them at same time.

Exercise: What locks are necessary for each op?

- read
  - user data sem.
- write
  - user data sem.
- poll
  - user data sem.
- fsync
  - user data sem.
  - What about delivery?
    - read user list r/w sem.
    - recipient's user data sem.
- release
  - user data sem. (and send message as above)

Exercise: What locks are necessary for each op?

(ioctl's)

- authenticate
  - read user list
  - user data sem. (if matched to a user)
- set password
  - write user list
  - (no need for user data sem.)
- write message
  - (may need to send message)
  - read user list
  - sender's user data sem. (if recipient validated)
- delete message
  - user data sem.

Exercise: What locks are necessary for each op?

- add new user
  - write user list
  - (no need for user data sem.;
    no one can authenticate while we have write lock on user list)

- delete user
  - write user list
  - user data sem. (MUST synchronize with all ops somehow!)