Instructor Notes

HYDRA: The Kernel of a Multiprocessor Operating System
W. Wulf, E. Cohen, W. Corwin, A. Jones, R. Levin, C. Pierson, and F. Pollack
Communications of the ACM 17(6), June 1974, pp. 337-344.

1. Hydra is an example of a kernel or nucleus of an OS. As such, what were its goals?

Background: Name - many-headed dragon - Greek
"many-headed" OS for multiprocessors
16 proc PDP-11s

This paper: philosophy of system - PROTECTION

Many papers on Hydra - more details on capabilities

Little eval

- multi-processor env.
- separation of mechanism + policy
- structured programming / modularization
- reject strict hierarchy (THE) (flex)

-PROTECTION - ~~no~~ apply uniform way throughout

- Reliability

2. What is the role of HYDRA?

- support abstracted notion of resource (objects)

- push idea that "everything is an object" to extreme

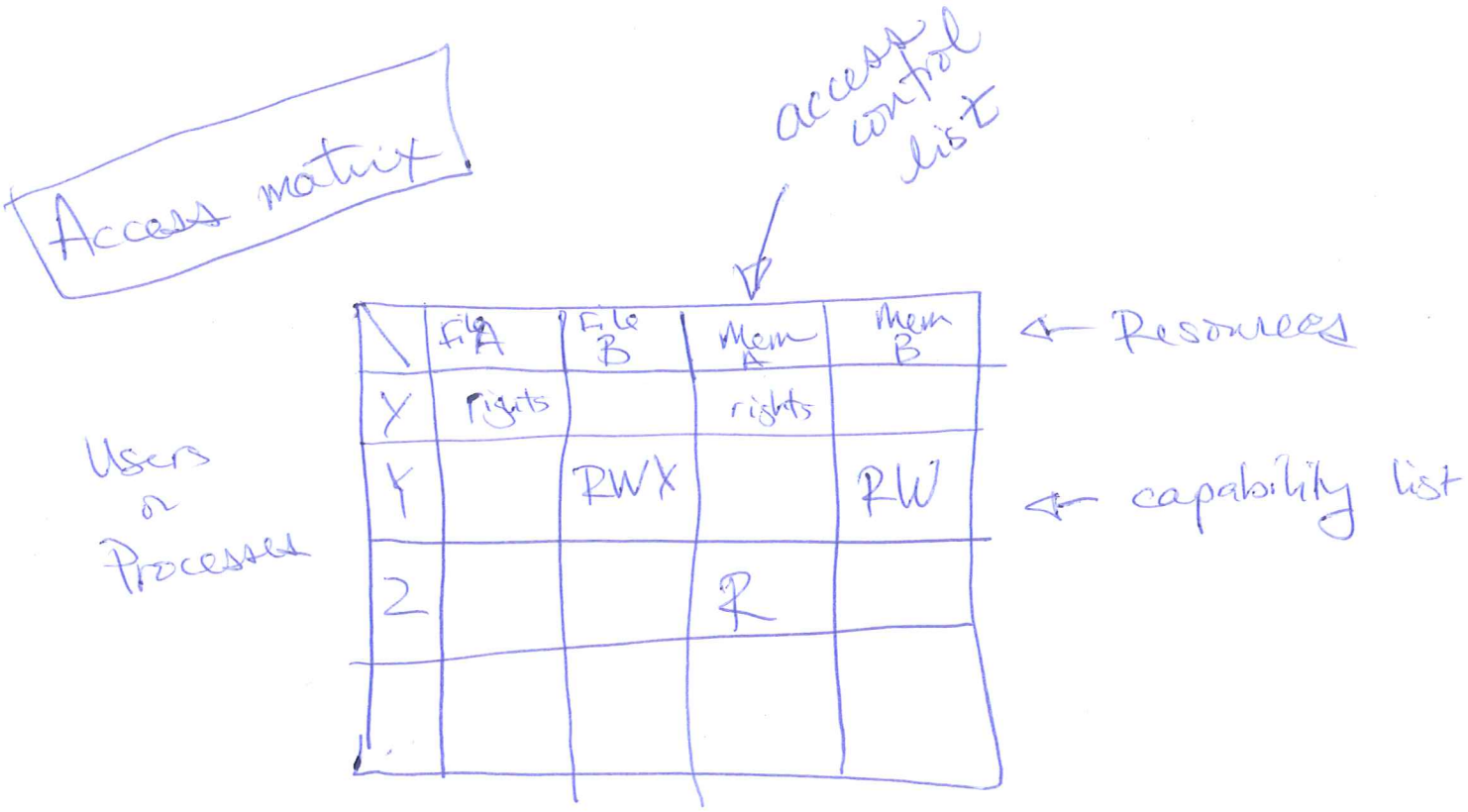
- good for research

3. What does each object in HYDRA contain?

PROCEDURE, LWS, PROCESS, FILES, SEMS, DIRS

- TYPE - classify, identify valid ops
- Unique name - id instance
- Representation
  - Data - value
  - Capability list - give access to other objects

4. What other options exist ~~instead~~ for protection instead of capabilities? Where are other approaches popular?



ACLs

- Popular in file system
- store permissions in each i-node

5. What does a capability contain? HYDRA capabilities contain generic (kernel) and type-specific (auxiliary) rights. Generic rights include rights such as copying an object, getting, putting data of an object; manipulating capabilities (read, deleting, adding). Why are type-specific rights needed?

1) reference to an object (instance name)
   → knowing name is not sufficient
2) access rights (bit vector) - fixed length
   1011000 ← can or can't do

- split into generic + type-specific

Type-specific

- Use to implement policy for new type (bibliography)
  - add, print, change

- Separate policy + mechanism
  (Hydra does not know policy)

6. One of the most important properties of capabilities is that they can't be forged. How can this be ensured? Can you think of where capabilities are used in UNIX?

- HW or OS support

1) Tag: Every word of mem is tagged (user can't set)
   1: cap
   0: other

   User processes can't write cap words

2) Segmentation:
   - Use mem prot. mechanisms to partition caps from data;
   - Users don't have perm. to caps

UNIX? hint: opaque handle
users can't change 'internals'

File descriptor
- handle given to user process
- can't change internal ~~cap~~ rights
- no use copying to someone else

7. What is in an object of Type Procedure (i.e., Name, Data, and Capability list)? What is a caller-independent capability? What is a caller-dependent capability and how is it implemented?

Name: Foo

Data: Code + static data

Cap list: caller-independent caps (local vars)

dependent: caps passed in

→ Templates

- cap type, needed rights

FILE	0010
foo	1010 ✓
bar	1100 X

→ No interpretation of rights by kernel

- Procedure developer defines

Sep. policy from mechanism

8. What happens when a procedure is called? What is problematic about this and what is the solution?

CALL proc-object, ret slot for cap,
cap. w/ mask$_1$, cap$_2$ w/ mask$_2$

1) jmp to kernel (must have right to call this procedure!)
2) check parameter TYPE + rights
3) create new LNS (push on stack)
4) construct new capabilities (mask + caller-independent)
5) jmp into code

→ Jmp to kernel is costly

Opt: don't do this for all procedures (just boundary ones)

9. Why is rights amplification useful? Can you think of an example of where this is used in UNIX? Why can masking away some rights be useful?

- may need additional rights to perform useful work

- e.g. type dependent: print
  → need to read

- only exists during procedure

UNIX?

- setuid - get rights of root (or another user) for well-defined process

(Must have amplification right - only defining procedures have it)

Mask?

- Do not trust procedure you are calling
- e.g. proc only needs to read:
  1st mask away write rights

10. What is an LNS (Local Name Space)? Why is it not the same as the Procedure Object? How does a Procedure access capabilities that are not local? Is this a correctness or a convenience issue?

- Record of execution env.
  - active procedure w/ instantiated caps

- Must be dynamic for recursion

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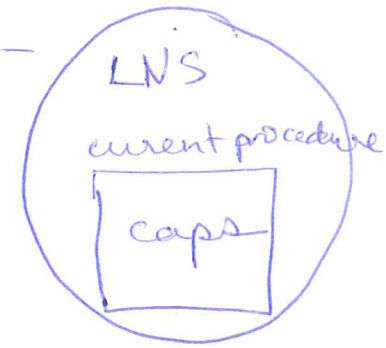

- use "Walk" right to each cap list of all objects

- Convenience so don't have to pass everything in

11. What is in an object of a Process Type? What types of operations on a Process should the scheduler have rights to? What operations should the scheduler NOT have rights to?

Name: pid
data: state, priority
c-list: stack of LNSes

Good ops: Start + Stop

Not: Read or modify data or caps
- don't know what process is doing

12. What are the strengths of Hydra capabilities? What are their problems?

- Elegant
- Separates mechanism (protection) from policy (security)
- ~~Complete~~ flexibility + Power
- Uniform mechanism
- Non-hierarchical

Problems:

- Complex, hard to use
  - Hydra never completed, no real users
- Overhead of kernel calls or procedure calls to check caps
- Space for caps