Lab 2

Part 2

Monitors in xk

- Lock
  - xk condition variable API only supports spinlock (an impl. choice)
- Condition
  - the shared data that threads are synchronizing on
  - for wait/exit this would be child's state
- Condition Variable
  - the waiter list is tracked by the process table
  - proc in SLEEPING state with the same `chan` are part of the same CV
  - `chan` is a pointer, can be anything (think of it as a cv identifier)

Sleep, Wakeup, and Chan

- sleep(void* chan, struct spinlock* lk)
  - atomically release your current lock and grabs the process table (ptable) lock
    - if your current lock is the ptable lock do nothing
    - why might your current lock be the ptable lock?
  - sets myproc()->state to SLEEPING
  - sets myproc()->chan to whatever channel we are waiting on
  - yields so that scheduler can run another process

Sleep, Wakeup, and Chan

- wakeup(void* chan)
  - acquires the process table lock
  - looks for all SLEEPING processes with the given channel (chan)
    - sets each proc->state to RUNNABLE (ready)
    - proc->chan is also cleared to NULL

Monitors in xk

- You will use monitors to implement wait(), exit(), pipe() for lab2
- sleep in synch.c is not the sleep system call

sleep = wait
wakeup = broadcast
no equivalent in xk = signal

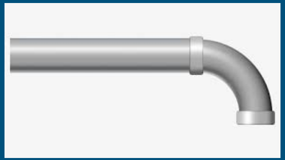
```c
struct fridge {
  struct spinlock lk; // assume initialized
  int yogurt = 0;
  int strawberry = 0;
}

void make_breakfast(struct fridge* fridge) {
  acquire(&fridge->lk);
  while (fridge->yogurt == 0 && fridge->strawberry < 2) {
    // temporarily release the lk when we sleep
    // so that the fridge state may be accessed and modified
    // when sleep returns, lk is acquired again (implicitly)
    sleep(fridge, &fridge->lk);
  }
  // consume the yogurt and strawberry
  fridge->yogurt = 0;
  fridge->strawberry -= 2;
  release(&fridge->lk);
}

void fill_fridge(struct fridge* fridge) {
  acquire(&fridge->lk);
  fridge->yogurt += 1;
  fridge->strawberry += 2;
  wakeup(fridge);
  release(&fridge->lk);
}
```

Lab 2 - Pipe

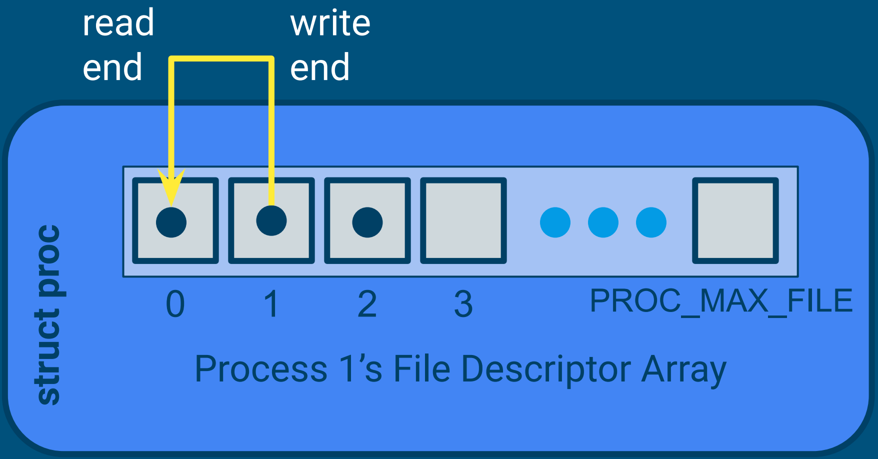
pipe(fds)

- Creates a pipe (kernel buffer) for process to read and write
- From the user perspective: returns two new file descriptors
  - fds[0] = “read end”, not writable
  - fds[1] = “write end”, is not readable
- You’ll want to make this compatible with existing file syscall interface
- Pipe allows processes to communicate with each other
  - parent opens a pipe, forks a child, and now they both have access to the pipe ends
  - typically one process only leaves one end open (closes the read end or the write end)

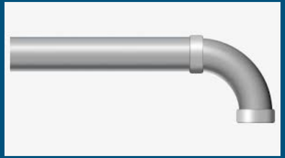
Pipes



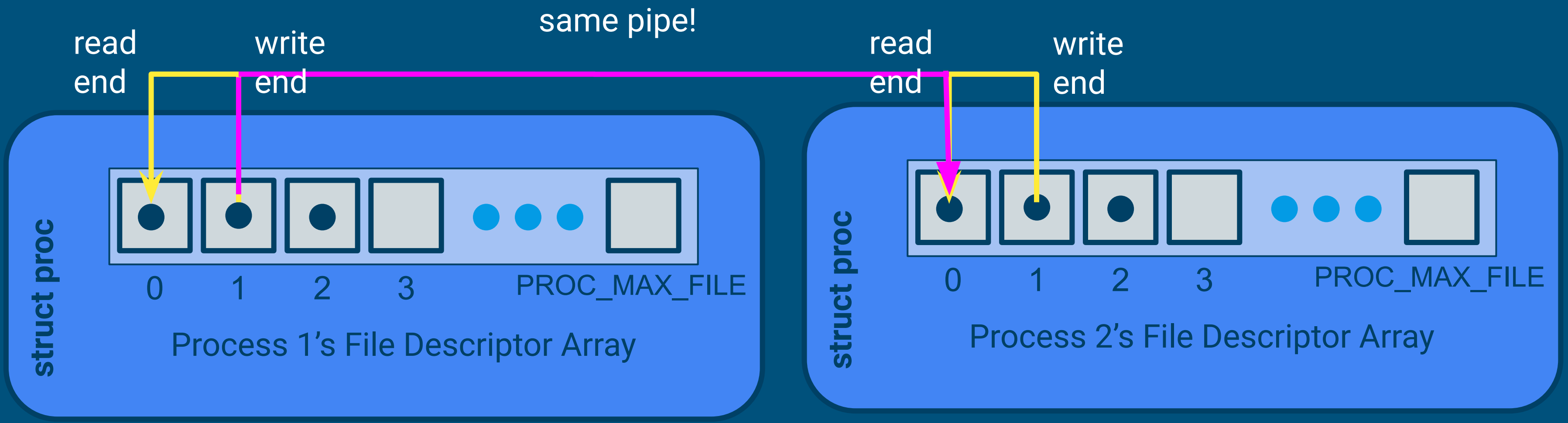
- A mechanism for process communication
- By calling sys_pipe, a process sets up a writing and reading end to a “holding area” where data can be passed between processes



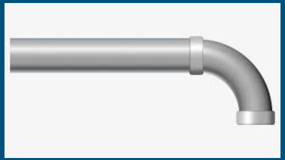
Pipes



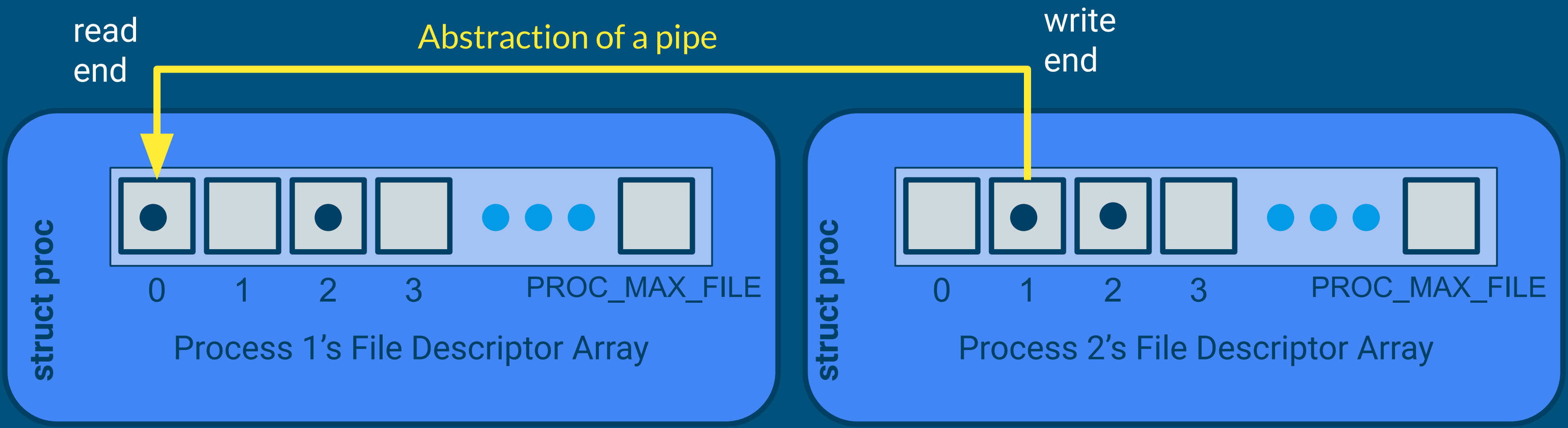
- Process 1 calls fork(), fd table is duplicated



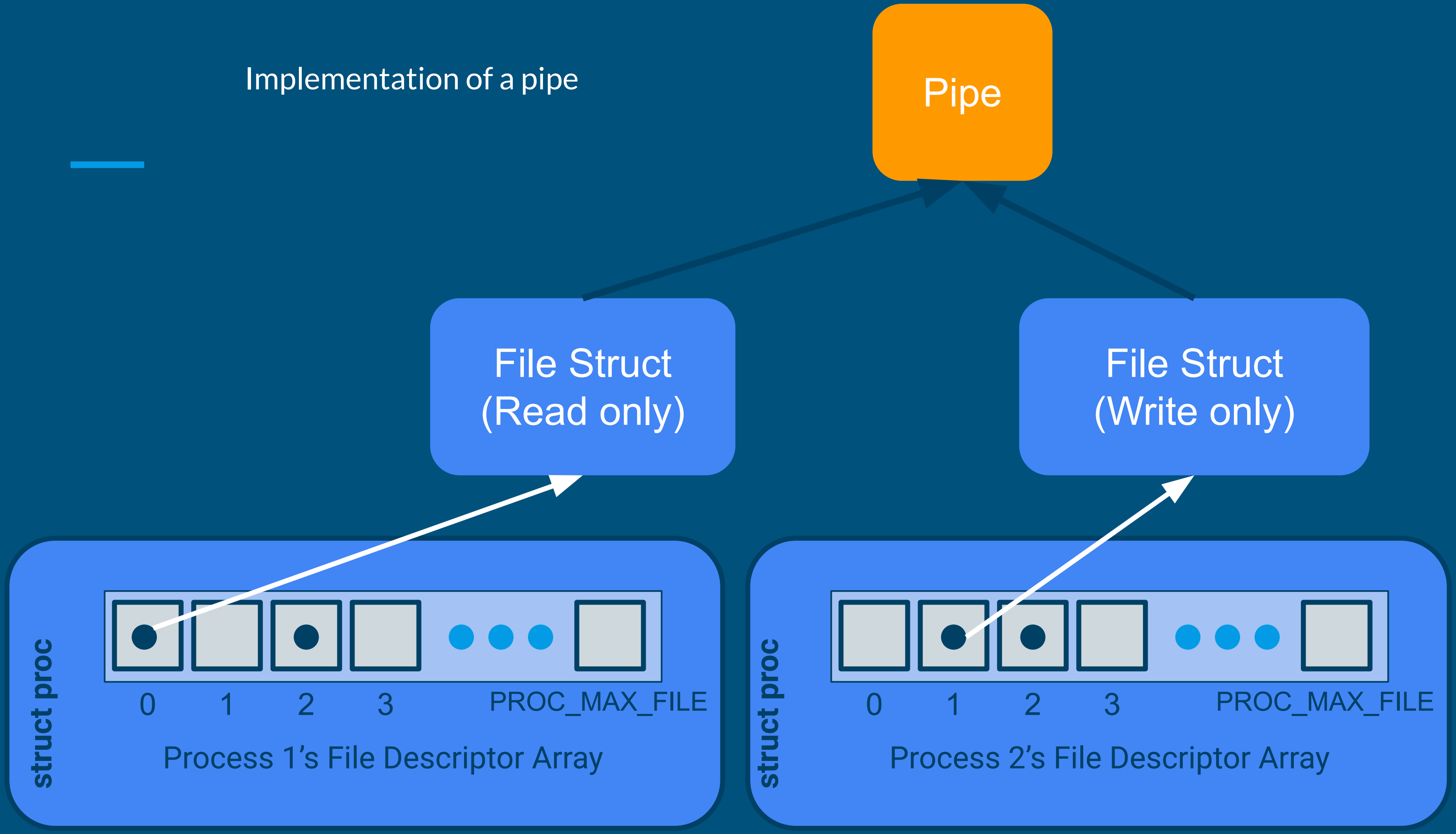
Pipes



- Process 1 close(1), process 2 close(0)
- And now we have a pipe across processes



Implementation of a pipe



Pipes

- Where should pipe be allocated?
  - pipes should be allocated at runtime, as requested
  - how does xk do dynamic memory allocation?
    - (hint: kstack is also dynamically allocated)
- When can you free the pipe and its buffer?
  - remember there may be multiple read ends and write ends
- Can we always write to or read from the buffer? (Hint: bounded buffer sync)
  - What if there's no room to write, or no data to read?
  - What happens if all read/write ends are closed?
- Pipe operations go through file syscall
  - Need a way to determine if a struct file is an inode or a pipe

Pipes Impl. Tips

- What metadata/information do you need for pipe?
  - offset to read from
  - offset to write to
  - whether the read end is still open
  - whether the write end is still open
  - # of bytes available in the buffer
  - lock and condition variables
- Similar to the bounded buffer problem

Lab 2 - Exec

exec(program, args)

- Fully replaces the current process; it does not create a new one
- How to replace the current process?
  - need to set up a new virtual address space and new registers states
  - and then switch to using the new VAS and register states
  - file descriptors and pid remain the same

exec(program, args)

- Setting up a new virtual address space
  - `vspaceinit` for initialization
  - `vspaceloadcode` to load code
  - `vspaceinitstack` to allocate stack vregion
    - you still need to populate user stack with arguments
    - `vspacewritetova` to write data into the stack of the new VAS
  - `vspaceinstall` to swap in the new vspace
  - `vspacefree` to release the old vspace
- The swapover to the new vspace can be tricky to get right!
  - Look at what vspacefree does

exec(program, args): args setup

int main(int argc, char** argv)

argc: The number of elements in argv

argv: An array of strings representing program arguments

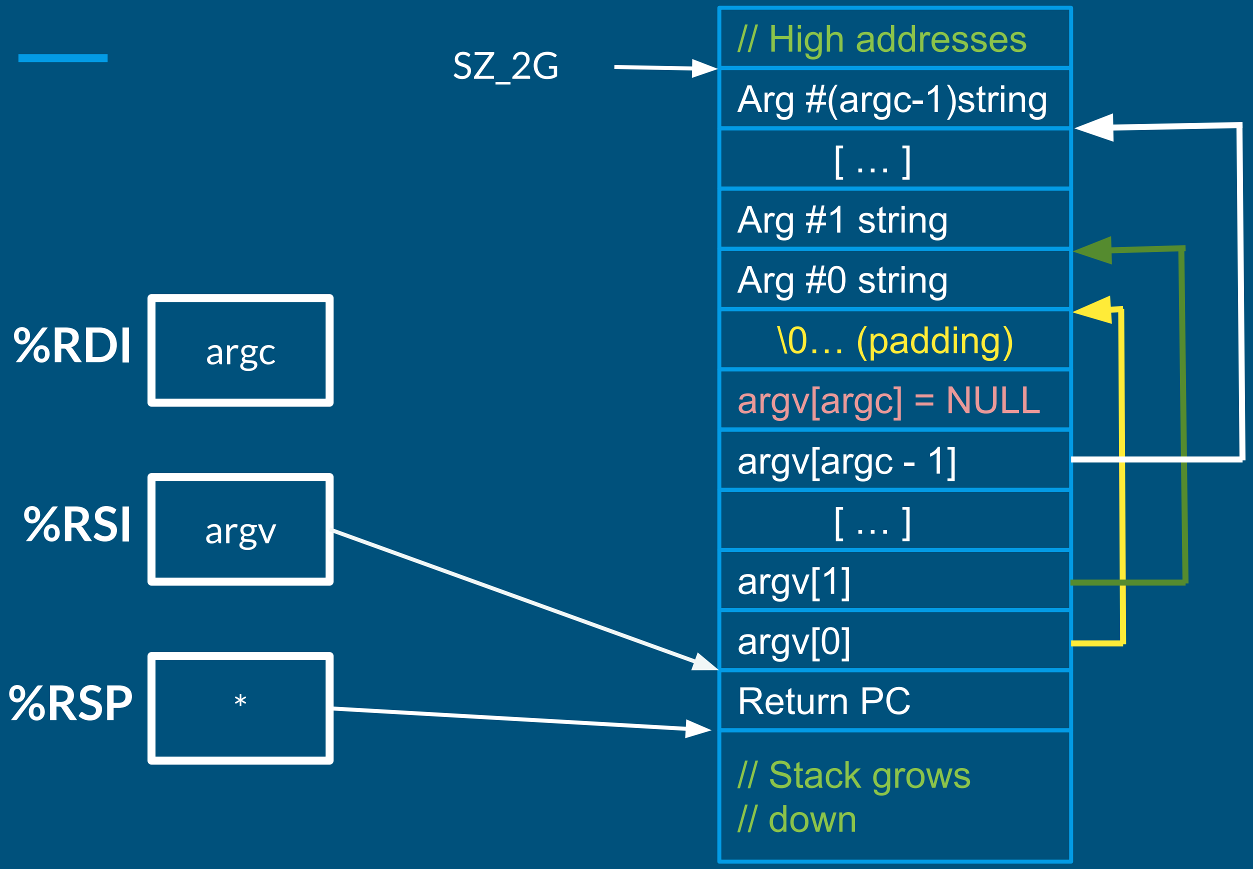
- First is always the name of the program
- Argv[argc] = 0

X86_64 Calling Conventions

- %rdi: holds the first argument
- %rsi: holds the second argument
  - %rdx, %rcx, %r8, %r9 comes next
  - overflows (arg7, arg8 …) onto the stack
- %rsp: points to the top of the stack (lowest address)

- Local variables are stored on the stack
- If an array is an argument, the array contents are stored on the stack and the register contains a pointer to the array's beginning

Stack For User Process



- Since argv is an array of pointers, %RSI points to an array on the stack
- Since each element of argv is a char*, each element points to a string elsewhere on the stack
- Why? Alignment
- Why NULL pointer? Convention

Questions?

Autograder Tips

- Autograder runs each test individually and then all part1/part2 tests
- part1 and part2 tests are run with make ICOUNT=2/4/6/8/10
    - ICOUNT is an argument to the Makefile
        - should make your bug show up more consistently (per configuration)
        - vary the amount of instruction interleaving (with different icount values)
        - ICOUNT is default to 10 when you run make qemu
    - If your kernel fails on certain ICOUNT config, you can reproduce it locally with make qemu ICOUNT=2/4/6/8/10 to debug

Debugging Tips: Trap Errors

- Trap Errors
  - `unexpected trap 14 from cpu 0 rip ffffffff80102f27 (cr2=0x0)`
  - `trap 14`: page fault, invalid memory access (most of the time)
  - `rip ffffffff80102f27`: line of code caused the page fault
  - `cr2=0x0`: the memory address that caused the page fault

```
(gdb) info line *0xffffffff80102f27
Line 41 of "kernel/sysfile.c"
   starts at address 0xffffffff80102f23 <sys_write+85>
   and ends at 0xffffffff80102f2d <sys_write+95>.
```

```
40    int *a = NULL;
41    *a = 4;
```

For more details, check out debugging.md

Debugging Tips: Record & Replay

Starting with lab2, there are multiple processes, meaning more concurrent accesses to the kernel code, which might make bugs harder to reproduce.

`make qemu-record`

record all external events to a log file

helpful if you can record the race condition

`make qemu-gdb-replay    (pair with make gdb)`

replay according to the log file, but with gdb (similar to make qemu-gdb)