CS 241 Honors
Lecture 4 – Kernel

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What to go over

- Processes and Threads
- Linking and Loading
- System Calls
- Completely Fair Scheduler

Motivation

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    write(1, "Hello world!", 12);
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int main(){
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- **void kfree(const void* objp)** Self explanatory, frees the pages for later usage.
- **mmap(void *addr, size_t length, int prot, int flags, int fd, off_t offset)** Takes a file, puts in to memory (it's a vast simplification, we can and have had another lecture on this).

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- The first thing the kernel does is start init (the main process for your operating system).
- Init does a lot of things. One important thing it does is initializing fork(), the magical library call that starts the entire process.
- Then init sees what run level you are running at. Init then runs the appropriate startup scripts to start all the processes for your operating system.

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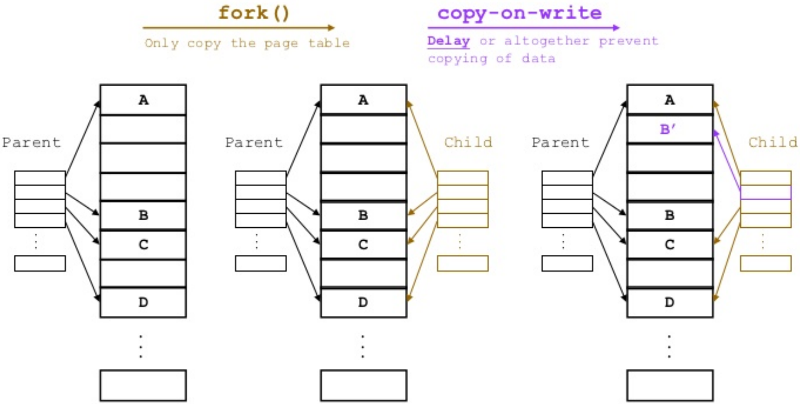
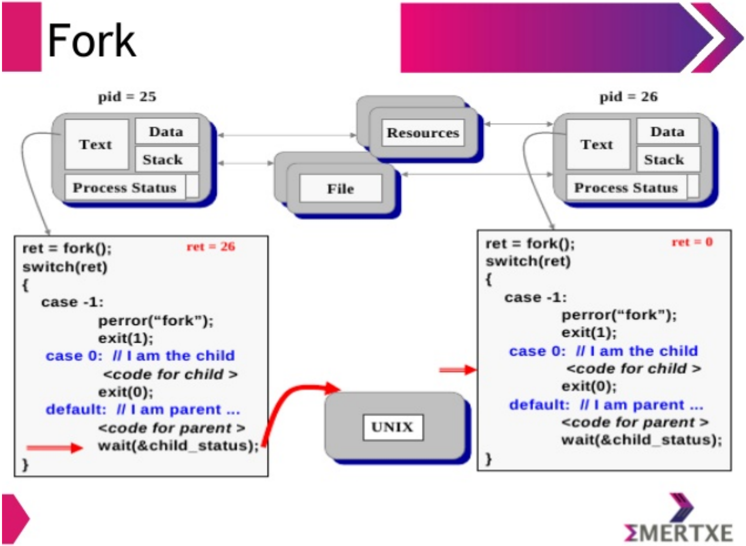
- Fork copies the file descriptors, page tables, signal handlers using kmalloc.
- Imagine in the linux kernel there is a struct with all of this stuff – that is what a process essentially is.

Process Creation – Copy-on-Write



Starting a process



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- The kernel then dynamically links libraries (to be explained later). The kernel also sets the pages that the old processes had to be destroyed on exec.
- The kernel resets registers and sets the stack pointer to the entry point of the main function. And finally, does the jump to the entrypoint. Your program is started!

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- We use pthreads! Threads in user-space.
- But to the kernel, there are no things as threads.

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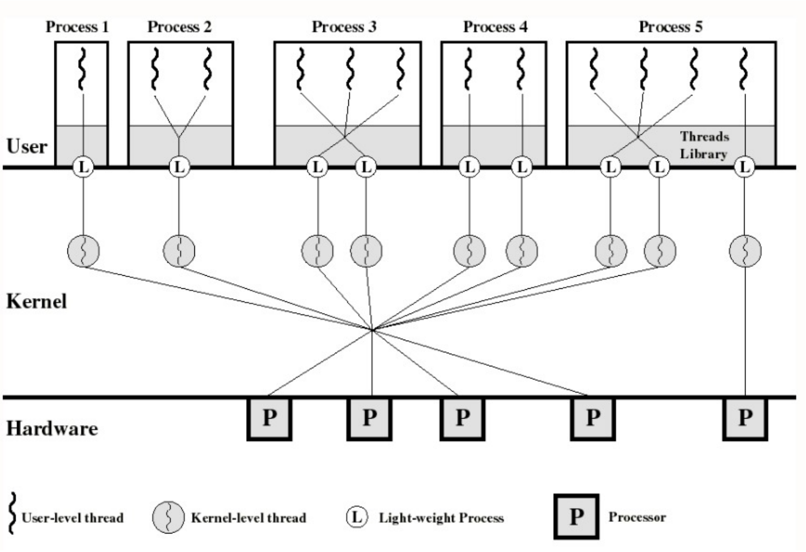
- The completely fair scheduler then handles running the threads.
- This abstraction is really cool – that is why in the systems literature/papers *everything* is a process.

Threading Start - pthread_create



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- Then the pthread is added to the pthread table, and returns out of the pthread function. Scheduling the process is left up to the completely fair scheduler.

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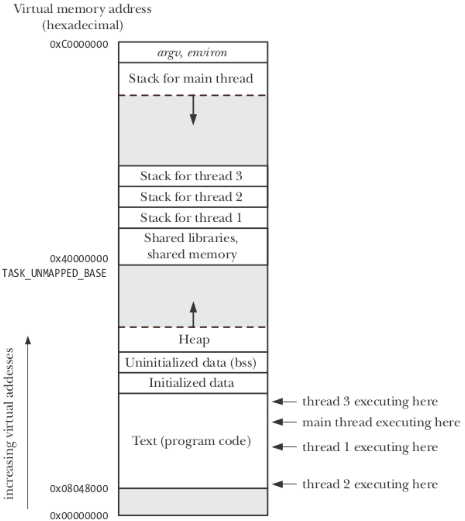

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- Race conditions! All the fun stuff from processes
- (The kernel does know it's supposed to be treated as a thread and uses group scheduling for efficiency)

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- Return the stack back to the program.

Linking and Loading

Motivation, Again

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What are we even talking about?

There are two types of libraries, those compiled with your programs and those that are linked dynamically at runtime. There are many benefits to use programs that get compiled with your program, but some drawbacks.

Cost-Benefit Analysis: Compile-Time Libraries

Benefits

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Drawbacks

- Updating is often tedious
- Your executable is bigger
- Your library cannot be reused by other applications

Solution: Dynamic Libraries

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- Reduce the size of your executable
- That library can be used by other applications.

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- Have your code jump to the pointer and the pointer jump to the actual function

Where is the table stored

"In Unix-like systems that use ELF for executable images and dynamic libraries, such as Solaris, 64-bit versions of HP-UX, Linux, FreeBSD, NetBSD, OpenBSD, and DragonFly BSD, the path of the dynamic linker that should be used is embedded at link time into the .interp section of the executable's PT_INTERP segment. In those systems, dynamically loaded shared libraries can be identified by the filename suffix .so (shared object)."
- Wikipedia

So what does that mean?

Exec fills in the references to the library calls in the lookup table in the PT_INTERP segment of the program. Whenever the program makes a call to that library then the program will jump to the lookup table which will jump to the appropriate place in memory, executing the function and return control back to your function.

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- When a process is done, reduce the reference count and return the page back to the system if need be.

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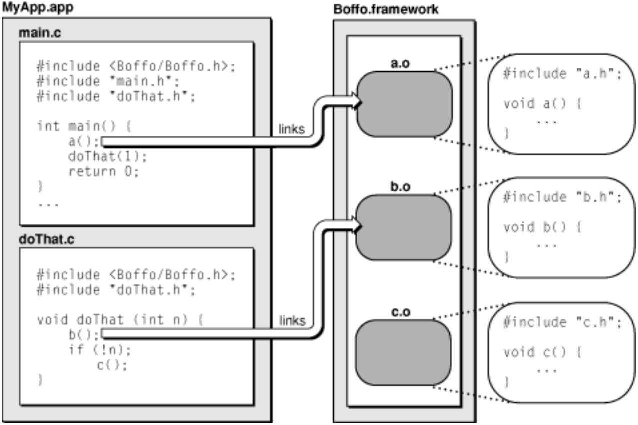

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- An example if we have time.

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- But there are always tradeoffs so DLLs are here to stay.

System Calls

Motivation, Again, Again

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- These are vital to change the state of the system, or to communicate with other processes for example

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- Kernel Space still needs to be exposed to system calls.

How do we call a system call?

Typically C library calls call system calls but here is some x86 to get the job done.

```
_start:
movl $4, %eax    ; use the write syscall
movl $1, %ebx    ; write to stdout
movl $msg, %ecx  ; use string "Hello World"
movl $12, %edx   ; write 12 characters
int $0x80        ; make syscall

movl $1, %eax    ; use the _exit syscall
movl $0, %ebx    ; error code 0
int $0x80        ; make syscall
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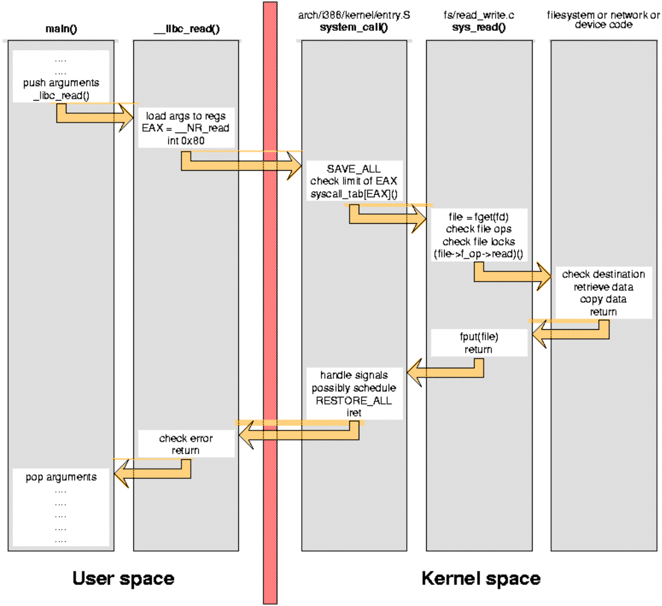

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- Demo if I can hack this kernel solution together

Completely Fair Scheduler

I promise last time.

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- So how does the CPU run all these processes? It switches between them really fast using what we call a scheduler.
- This is essentially a dining philosopher problem that is solved by pre-emption. The kernel tells processes when they can hog resources like CPUs and tells them to stop whenever else.

Deadlock solved, now starvation

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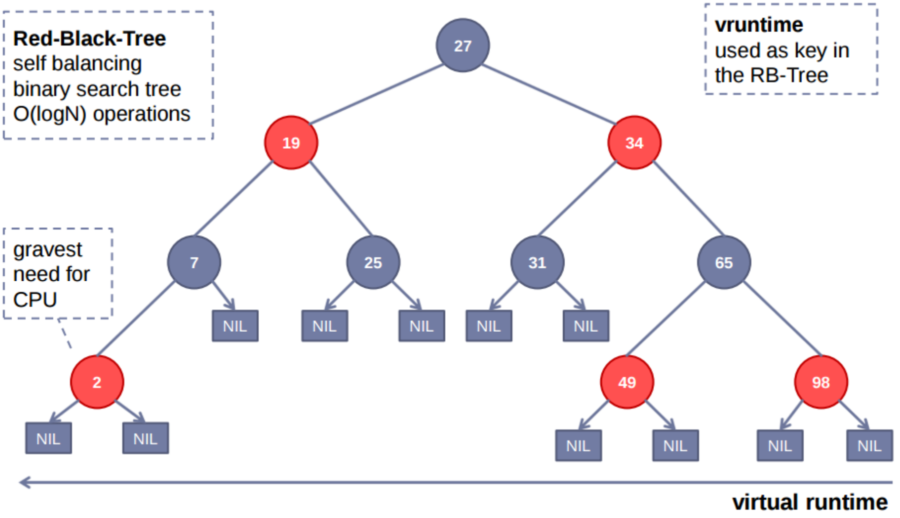
- (Nice values are the kernel's way of giving priority to certain processes, the lower the higher priority)
- The kernel chooses the lowest one based on this metric and schedules that process to run next, taking it off the queue. Since the red-black tree is self balancing this operation is guaranteed $O(log(n))$ (selecting the min process is the same runtime)


Red-Black-Tree
self balancing
binary search tree
O(logN) operations
vruntime
used as key in
the RB-Tree
gravest
need for
CPU
27
19
34
7
25
31
65
2
49
98
NIL
NIL
NIL
NIL
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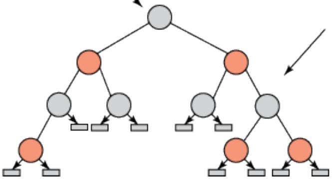
NIL
virtual runtime

Threads!

```
struct task_struct {
  volatile long state;
  void *stack;
  unsigned int flags;
  int prio, static_prio normal_prio;
  const struct sched_class *sched_class;
  struct sched_entity se;
  ...
};
```

```
struct sched_entity {
  struct load_weight load;
  struct rb_node run_node;
  struct list_head group_node;
  ...
};
```

```
struct ofs_rq {
   ...
   struct rb_root tasks_timeline;
   ...
};
```



```
struct rb_node {
  unsigned long rb_parent_color;
  struct rb_node *rb_right;
  struct rb_node *rb_left;
};
```

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- The CFS tends to schedule groups of processes together – taking advantage of cache coherency, open files, open sockets etc.
- The CFS handles higher priority and long running processes fairly so no process fades away into the scheduling abyss.

CFS Problems

- Groups of processes that are scheduled may have imbalanced loads so the scheduler roughly distributes the load. When another CPU gets free it can only look at the average load of a group schedule not the individual cores. So the free CPU may not take the work from a CPU that is burning so long as the average is fine.

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- If a group of processes is running, on non adjacent cores then there is a bug. If the two cores are more than a hop away, the load balancing algorithm won't even consider that core. Meaning if a CPU is free and a CPU that is doing more work is more than a hop away, it won't take the work (may have been patched).

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- After a thread goes to sleep on a subset of cores, when it wakes up it can only be scheduled on the cores that it was sleeping on. If those cores are now bus

Conclusion

Any questions? Thanks for sticking along!