xv6©-rev10
(Copyright Frans Kaashoek, Robert Morris, and Russ Cox.)
Scheduler

Carmi Merimovich

Tel-Aviv Academic College

November 20, 2017

Context

```
kinit1(end, P2V(4*1024*1024)); // phys page alloca
kvmalloc();        // kernel page table
  ⋮
seginit();         // set up segments
  ⋮
pinit();           // process table
  ⋮

  ⋮
kinit2(P2V(4*1024*1024), P2V(PHYSTOP)); // must co
userinit();        // first user process
mpmain();
```

Auxiliary context

- The primary processor begins its C code in **main()**.
- The auxiliary processors begins their C code in **mpenter()**.
- The state on entering either **main()** or **mpenter()** is the same.
- There is a separate stack of each processor.

```
static void mpenter(void) {
  switchkvm();
  seginit();
  lapicinit();
  mpmain();
}
```

mycpu()

```
2436 struct cpu* mycpu(void) {
  int apicid, i;

  if (readeflags()&FL_IF)
    panic("mycpu called with interrupts enabled\n");

  apicid = lapicid();
  for (i = 0; i < ncpu; ++i) {
    if (cpus[i].apicid == apicid)
      return &cpus[i];
  }
  panic("unknown apicid\n");
}
```

mpmain()

```
static void mpmain(void) {
  cprintf("cpu%d: starting %d\n", cpuid(), cpuid());
  idtinit(); // load idt register
  xchg(&(mycpu()->started), 1); // tell startothers()
  scheduler(); // start running processes
}
```

myproc()

```
struct proc *myproc(void) {
 struct cpu *c;
 struct proc *p;
 pushcli();
 c = mycpu();
 p = c->proc;
 popcli();
 return p;
}
```

scheduler

```
2758 void scheduler(void) {
  struct proc *p;
  struct cpu *c = mycpu();
  c->proc = 0;
  for(;;) { sti();
   acquire(&ptable.lock);
   for(p = ptable.proc; p < &ptable.proc[NPROC]; p++) {
    if (p->state != RUNNABLE) continue;

    c->proc = p;
    switchuvm(p);
    p->state = RUNNING;
    swtch(&c->scheduler, p->context);
    switchkvm();

    c->proc = 0;
   }
   release(&ptable.lock);
  }
```

scheduler() operation

- For each proc struct p with state RUNNABLE the following is executed:
  - **c->proc = p**;
  - **switchuvm()**.
  - **swtch()**.
  - **switchkvm()**.
  - **c->proc=NULL**.

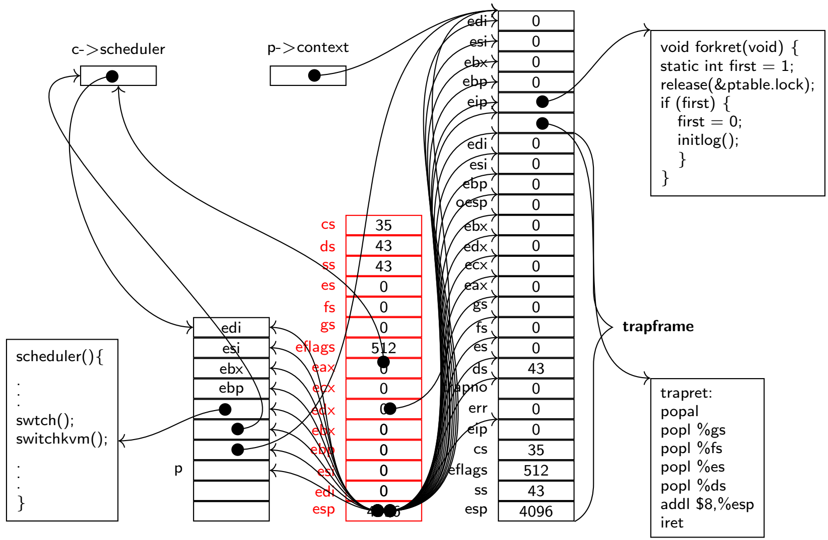
swtch()

```
.globl swtch
swtch:
 movl 4(%esp), %eax
 movl 8(%esp), %edx

 pushl %ebp
 pushl %ebx
 pushl %esi
 pushl %edi

 movl %esp, (%eax)
 movl %edx, %esp
```

```
 popl %edi
 popl %esi
 popl %ebx
 popl %ebp
 ret
```

The `eip` field of `context` is generated by the instruction calling `swtch`.

swtch() operation



Context switch

- Calling **swtch()**:
  - Creates a **context** structure on the current stack.
  - Stores the **cotext** structure address created in the first argument.
  - Load the **context** structure pointed to by the second argument.
- We are switching KERNEL contexts.
- User mode context of a process is loaded by the kernel side of the process.

Kernel context seems too small

- Where are **eax**, **ecx**, **edx**????
  - The **gcc** calling conventions deals with them!
- Where are **cs**, **ds**, and **ss**????
  - The base and limit fields are identical across all kernel sides.
  - So, they need to be loaded only on aech kernel entering.
- Where is **gdtr**????
  - The address and size fields are different across processors.
  - The base and limit MUST NOT change between kernel sides on the same CPU.
  - Since **gdtr** is privileged, it needs to be loaded ONLY on kernel initialization.

If switching to user mode is expected:

- The `tr` register should contain the index of a TSS descriptor.
- The `TSS` descriptor should point to a `taskstate` structure.
- The `ss0` and `esp0` fields should point to a valid kernel stack top.
- The above is ESSENTIAL for proper interrupt service in user mode.

switchuvm

```c
void switchuvm(struct proc *p) {
 pushcli();
 mycpu()->gdt[SEG_TSS] = SEG16(STS_T32A,
                               &mycpu()->ts,
                               sizeof(mycpu()->ts)-1, 0)
 mycpu()->gdt[SEG_TSS].s = 0;
 mycpu()->ts.ss0 = SEG_KDATA<<3;
 mycpu()->ts.esp0 = (uint)p->kstack + KSTACKSIZE;
 mycpu()->ts.iomb = (ushort) 0xFFFF;
 ltr(SEG_TSS << 3);
 if (p->pgdir == 0)
  panic("switchuvm: no pgdir");
 lcr3(v2p(p->pgdir)); // switch to new address space
 popcli();
}
```

`taskstate` (hardware structure)

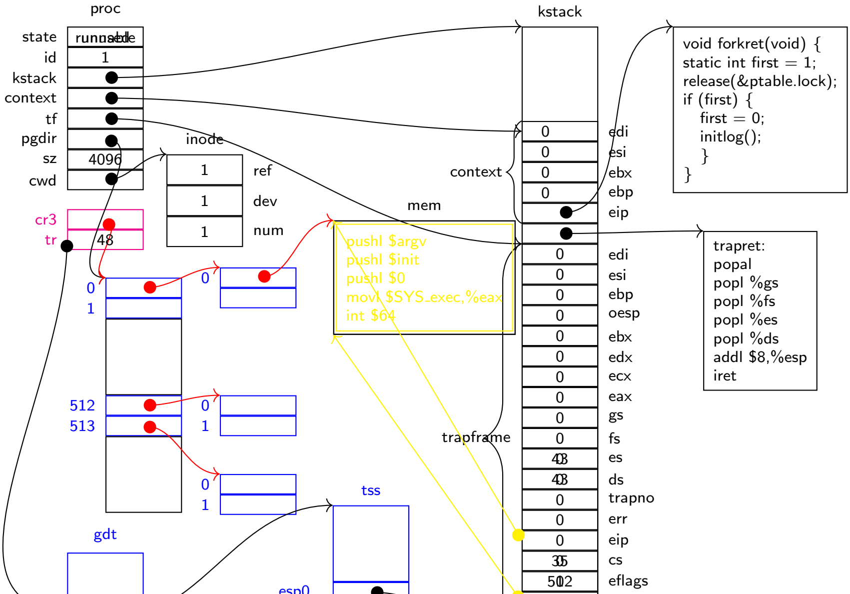
<table>
<tr><td colspan="2">link</td></tr>
<tr><td colspan="2">esp0</td></tr>
<tr><td></td><td>ss0</td></tr>
<tr><td colspan="2">esp1</td></tr>
<tr><td></td><td>ss1</td></tr>
<tr><td colspan="2">esp2</td></tr>
<tr><td></td><td>ss2</td></tr>
<tr><td colspan="2">cr3</td></tr>
<tr><td colspan="2">eip</td></tr>
<tr><td colspan="2">eflags</td></tr>
<tr><td colspan="2">eax</td></tr>
<tr><td colspan="2">ecx</td></tr>
<tr><td colspan="2">edx</td></tr>
<tr><td colspan="2">ebx</td></tr>
<tr><td colspan="2">esp</td></tr>
<tr><td colspan="2">ebp</td></tr>
<tr><td colspan="2">esi</td></tr>
<tr><td colspan="2">edi</td></tr>
</table>

<table>
<tr><td></td><td>es</td></tr>
<tr><td></td><td>cs</td></tr>
<tr><td></td><td>ss</td></tr>
<tr><td></td><td>ds</td></tr>
<tr><td></td><td>fs</td></tr>
<tr><td></td><td>gs</td></tr>
<tr><td></td><td>ldt</td></tr>
<tr><td></td><td>t</td></tr>
<tr><td>iomb</td><td></td></tr>
</table>

taskstate in C

```c
struct taskstate {
  uint link;
  uint esp0;
  ushort ss0;
  ushort padding1;
  uint *esp1;
  ushort ss1;
  ushort padding2;
  uint *esp2;
  ushort ss2;
  ushort padding3;
  void *cr3;
  uint *eip;
  uint eflags;
  uint eax;
  uint ecx;
  uint edx;
  uint ebx;
  uint *esp;
  uint *ebp;
  uint esi;
  uint edi;
  ushort es;
  ushort padding4;
  ushort cs;
  ushort padding5;
  ushort ss;
  ushort padding6;
  ushort ds;
  ushort padding7;
  ushort fs;
  ushort padding8;
  ushort gs;
  ushort padding9;
  ushort ldt;
  ushort padding10;
  ushort t;
  ushort iomb;
};
```

switchuvm


proc
state
id
1
kstack
context
tf
pgdir
sz
4096
cwd
cr3
tr
48
inode
1
ref
1
dev
1
num
0
1
512
513
0
0
1
0
1
gdt
mem
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
tss
esp0
ss0
16
kstack
context
trapframe
edi
esi
ebx
ebp
eip
edi
esi
ebp
oesp
ebx
edx
ecx
eax
gs
fs
es
ds
trapno
err
eip
cs
eflags
esp
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
first = 0;
initlog();
}
}
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret

co-routines

- The `scheduler` switches to a process by using:

```
2478      swtch(&c->scheduler, p->context);
```

- A process leaves the cpu by returning to the `scheduler` using:

```
2516      swtch(&p->context, mycpu()->scheduler);
```

- We have here co-routines.

Event driven kernel

- At this point there is no more LINEAR EXECUTION of the kernel.
- The kernel as of now is EVENT DRIVEN.