xv6ⓒ-rev10
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The **fork** system call

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sys_fork

```
int sys_fork(void) {
 return fork();
}
```

fork()

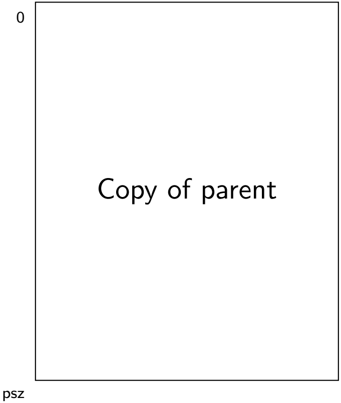
Recall:

- A child (of the invoker) process is created.
- The pid of the child process is returned to the invoker.
- The child process is (almost) identical to the parent process.
    - To the child, the return value of the system call is zero.
- So, how do we begin?

Child process state needed

eax	0
ebx	pebx
ecx	pecx
edx	pedx
ebp	pebp
esi	pesi
edi	pedi
esp	pesp
eip	peip

cs	pcs
ds	pds
ss	pss
es	pes
fs	pfs
gs	pgs



proc struct

How do we fill the fields of the new process?

```
  uint sz; // @proc->sz@
  pde_t* pgdir; // @Serious replication needed@
  char *kstack; // @probably allocproc()@
  enum procstate state; // @RUNNABLE@
  volatile int pid; // @allocproc()@
  struct proc *parent; // @proc@
  struct trapframe *tf; // @allocproc()@
  struct context *context; // @allocproc()@
  void *chan; // @0@
  int killed; // @0@
  struct file *ofile[NOFILE]; // @filedup()@ (when st
  struct inode *cwd; // @idup()@ (when studying fs)
  char name[16]; // @proc->name@
};
```

Needed work

- proc struct and friends.
- Filling `pgdir` requires considerable code replication.
- Replicatin ofile and cwd requires help from the relevant modules.

proc struct and friends

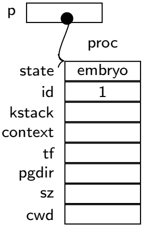
allocproc(): (1) Finding unused proc structure

```
2473 static struct proc *allocproc(void) {
      struct proc *p;
      char *sp;

      acquire(&ptable.lock);
      for(p = ptable.proc; p < &ptable.proc[NPROC]; p++)
       if (p->state == UNUSED)
        goto found;
      release(&ptable.lock);
      return 0;

     found:
      p->state = EMBRYO;
      p->pid = nextpid++;
      release(&ptable.lock);
```

allocproc(): (1) Operation



p

proc

state	embryo
id	1
kstack	
context	
tf	
pgdir	
sz	
cwd	

```
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
```

allocproc: (2) Initialize process kernel stack

```
  if ((p->kstack = kalloc()) == 0) {
   p->state = UNUSED;
   return 0;
  }
  sp     = p->kstack + KSTACKSIZE;
  sp    -= sizeof *p->tf;
  p->tf = (struct trapframe*)sp;
  sp    -= 4;
  *(uint*)sp = (uint)trapret;
  sp    -= sizeof *p->context;
  p->context = (struct context*)sp;
  memset(p->context, 0, sizeof *p->context);
  p->context->eip = (uint)forkret;
  return p;
}
```

allocproc: (2) Operation

	proc
state	embryo
id	1
kstack	
context	
tf	
pgdir	
sz	
cwd	

```
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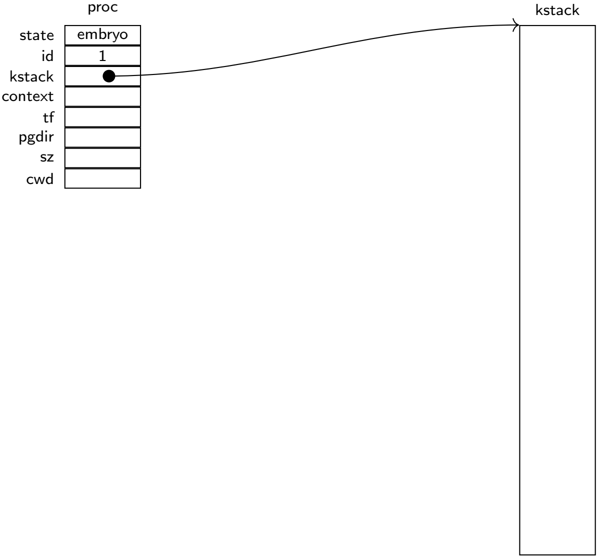

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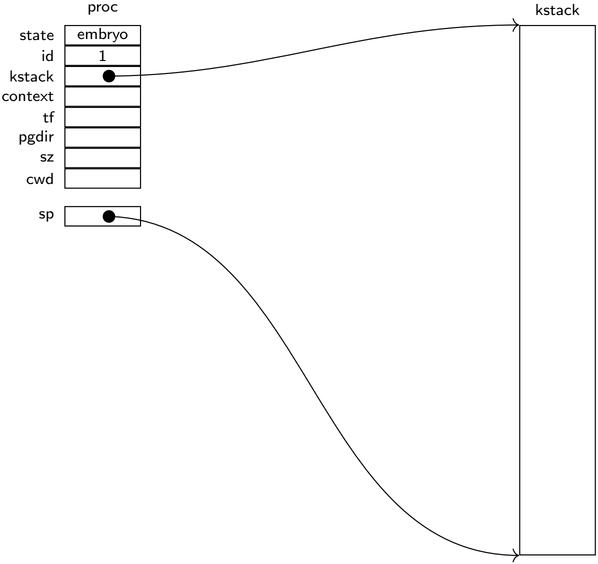

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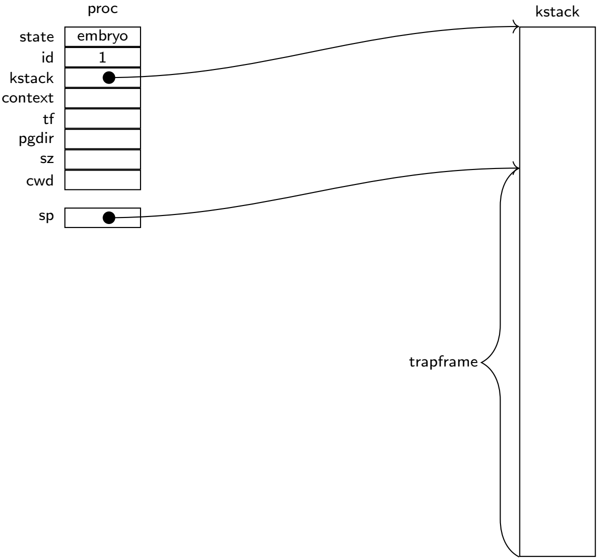

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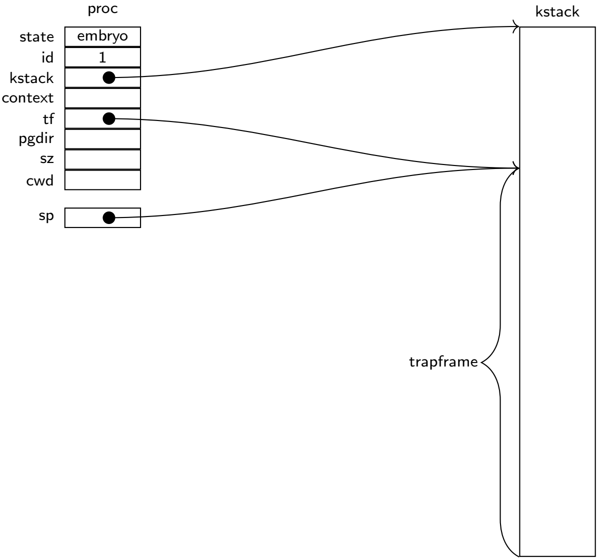

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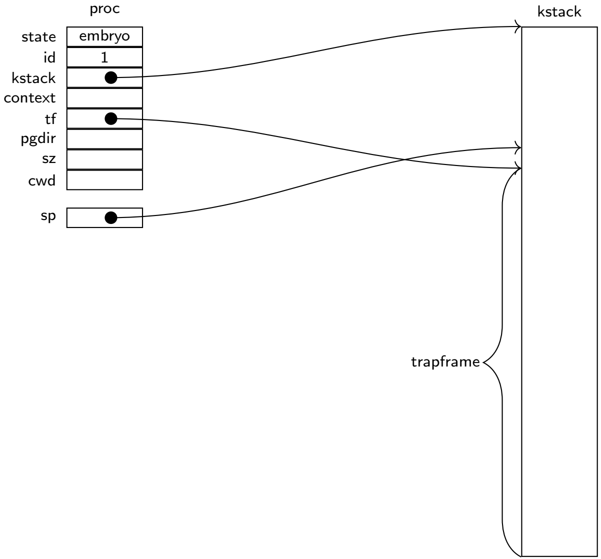

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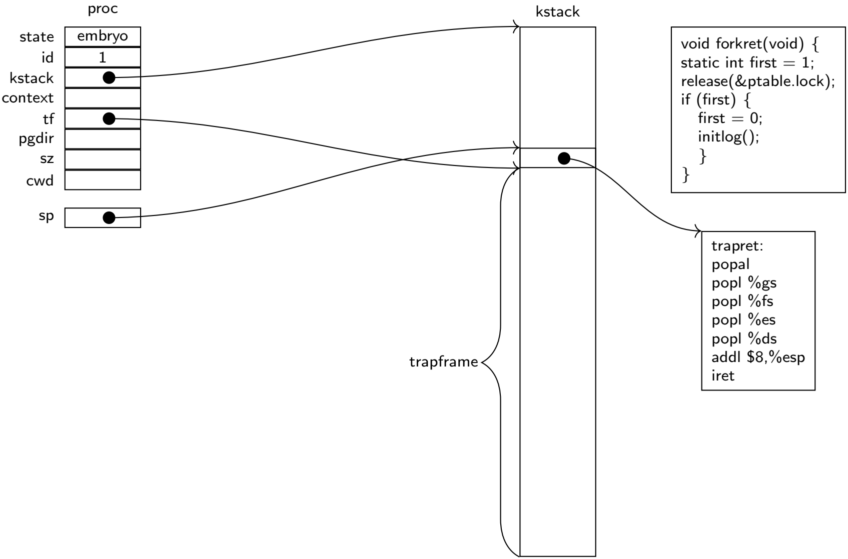

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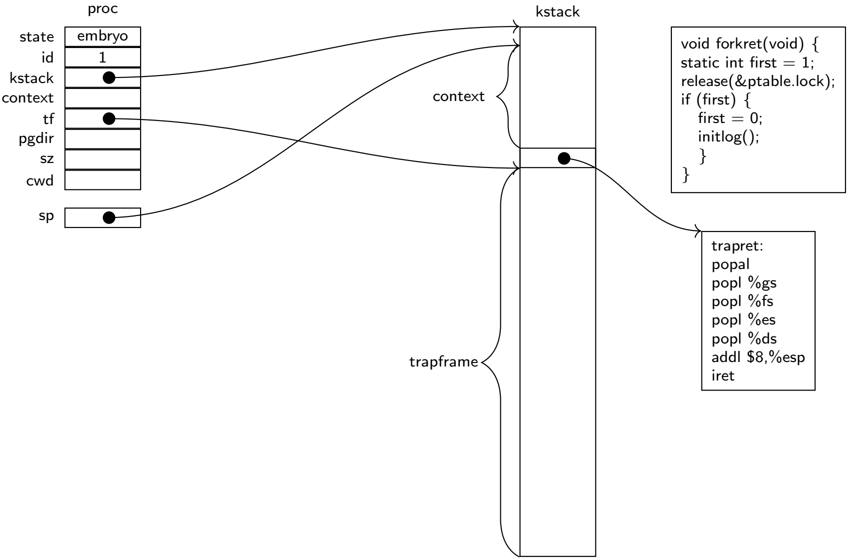

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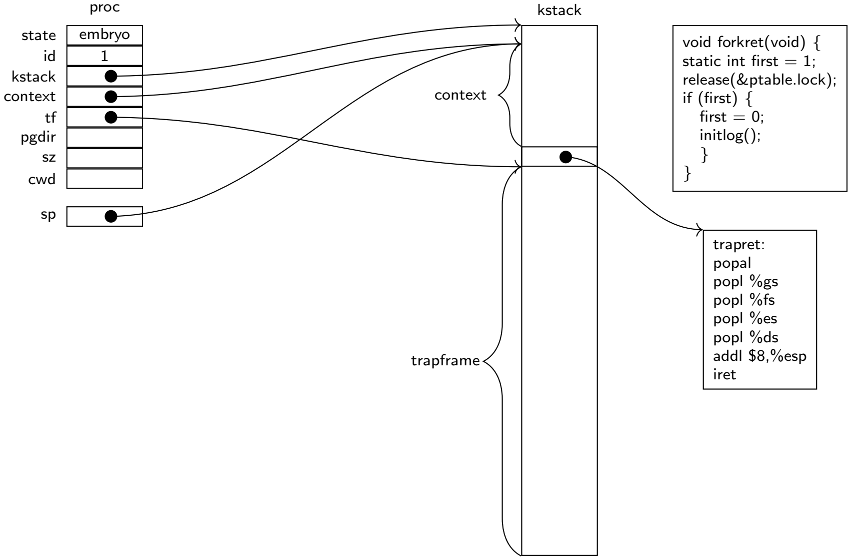

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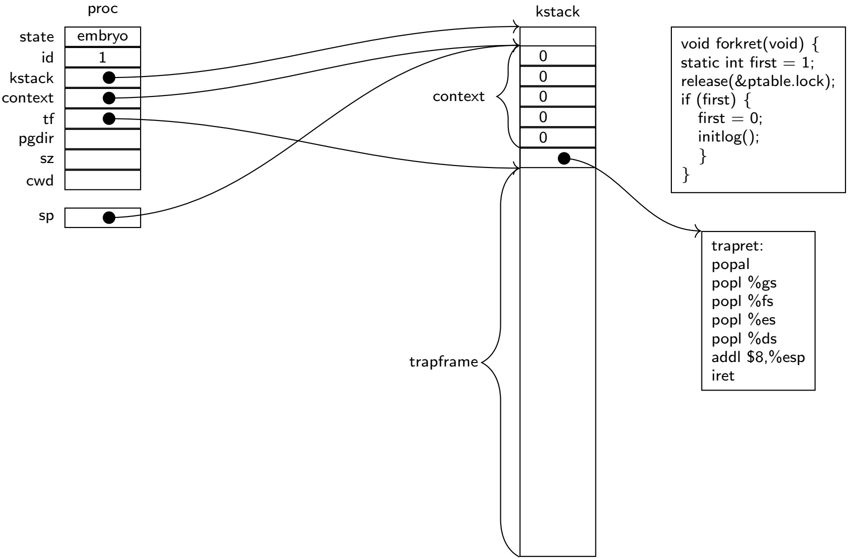

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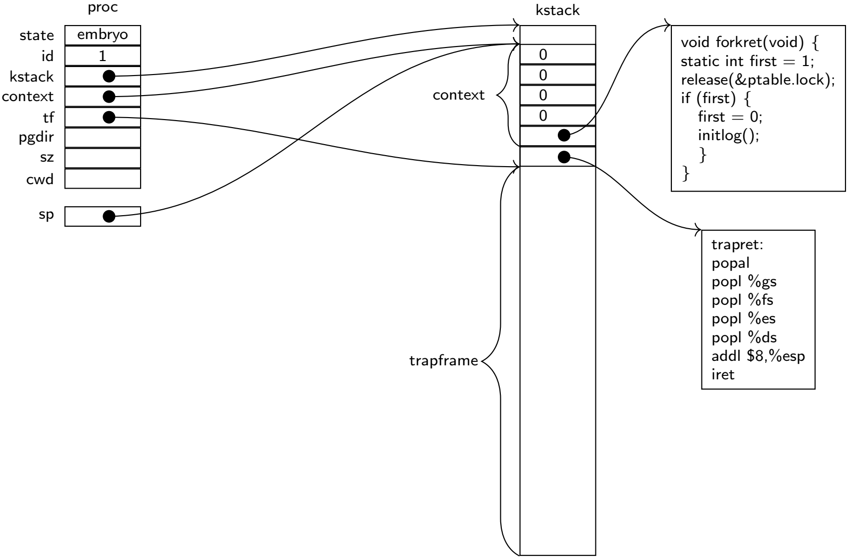

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```

User space replication

(two methods)

Replcation page 0 of current process only

Replicating current process first page

- Allocating new block of memory:

```
dst = kalloc();
```

- Copying. One of the following is possible:

1.
```
memmove(dst,0,4096);
```

2.
```
p = walkpgdir(myproc()->pgdir,0,0);
memmove(dst,p2v(PTE_ADDR(*p)),4096);
```

- This is of course useless as it is.

Create new address space

Replcation page 0 of current process only

Add mapping rules in the new address space to the replication

New address space and mapping

- Creating a new address space:

```
pgdir = setupkvm();
```

- Allocate and copy:

```
dst = kalloc();
p = walkpgdir(myproc()->pgdir,0,0);
memmove(dst,p2v(PTE_ADDR(*p)),4096);
```

- Adding translation rule:

```
mappages(pgdir, 0,4096,v2p(dst), (*p) & 4095);
```

Replcating means doing the copy and translation for each page.

Replicate and Map ALL user space pages

Replicating currnet process pages

NO ERROR CHECKING IN HERE!

```
pgdir = setupkvm();

for (va=0; va<myproc()->sz; va += PGSIZE) {
 kva = kalloc();
 memmov(kva, va, PGSIZE);
 pte = walkpgdir(myproc()->pgdir,va,0);
 mappages(pgdir,va,PGSIZE,v2p(kva),(*pte) & 4095);
}
```

- If there is allocation error, all previous allocations must be freed!
- We show freeing on the next slide.

Freeing address space

```
for (i = 0; i < 512; i++) {
 if ((pgdir[i] & PTE_P) == 0)
  continue;
 pgtbl = p2v(pgdir[i] & -4096);
 for (j=0; j < 1024; j++) {
  if (pgtbl[j] & PTE_P) {
   kfree(p2v(pgtbl[j] & ~4095));
  }
 }
 kfree(pgtbl);
}
for (i = 512; i < 1023; i++) {
 if ((pgdir[i] & PTE_P) == 0)
  continue;
 pgtbl = p2v(pgdir[i] & -4096);
 kfree(pgtbl);
}
kfree(pgdir);
```

xv6 code for user space replication

(More general than needed)

xv6 replicating and freeing address space

The following xv6 code replicates arbitrary address space.

- The code checks for allocation errors.
- It deallocates all previous allocation in case of failure.

copyuvm()

```
pde_t* copyuvm(pde_t *pgdir, uint sz) {
 pde_t *d; pte_t *pte;
 uint pa, i;
 char *mem;
 if ((d = setupkvm()) == 0)  return 0;
 for (i = 0; i < sz; i += PGSIZE) {
  if ((pte = walkpgdir(pgdir, (void *) i, 0)) == 0) panic
  if (!(*pte & PTE_P)) panic("copyuvm:␣page␣not␣present")
  pa = PTE_ADDR(*pte);
  if ((mem = kalloc()) == 0)  goto bad;
  memmove(mem, (char*)p2v(pa), PGSIZE);
  if (mappages(d, (void*)i, PGSIZE, v2p(mem),
        PTE_FLAGS(*pte)) < 0) goto bad;
 }
 return d;
bad:
 freevm(d);
 return 0;
}
```

freevm()

```
void freevm(pde_t *pgdir) {
 uint i;

 if (pgdir == 0)
  panic("freevm: no pgdir");
 deallocuvm(pgdir, KERNBASE, 0);
 for (i = 0; i < NPDENTRIES; i++) {
 if (pgdir[i] & PTE_P) {
  char * v = p2v(PTE_ADDR(pgdir[i]));
  kfree(v);
  }
 }
 kfree((char*)pgdir);
}
```

deallocuvm

```
deallocuvm(pde_t *pgdir, uint oldsz, uint newsz) {
 pte_t *pte;
 uint a, pa;
 if (newsz >= oldsz)  return oldsz;
 a = PGROUNDUP(newsz);
 for (; a < oldsz; a += PGSIZE) {
  pte = walkpgdir(pgdir, (char*)a, 0);
  if (!pte) a += (NPTENTRIES - 1) * PGSIZE;
  else if ((*pte & PTE_P) != 0) {
   pa = PTE_ADDR(*pte);
   if (pa == 0) panic("kfree");
   char *v = p2v(pa);
   kfree(v);
   *pte = 0;
  }
 }
 return newsz;
```

fork

- `allocproc`:
  - An `EMBRYO` `proc` struct is constructed.
  - A kernel stack is allocated.
  - An uninitialized `trapframe` is allocated.
  - An artificial `context` is constructed.
- The user space memory of the caller is replicated.
- A new matching page table is constructed.
- The `trapframe` of the caller is copied to the uninitialized `trapframe`.
- The `eax` field of the new `trapframe` is cleared.
- File pointers are replicated.
- Rest of the caller **proc** struct fields are copied to the new **proc** struct.

fork (1)

```
int fork(void) {
 int i, pid;
 struct proc *np;

 if ((np = allocproc()) == 0)
  return -1;

 if ((np->pgdir=copyuvm(myproc()->pgdir,myproc()->sz
                   == 0) {
  kfree(np->kstack);
  np->kstack = 0;
  np->state = UNUSED;
  return -1;
 }
```

fork (2)

```
  np->sz = myproc()->sz;
  np->parent = myproc();
  *np->tf = *myproc()->tf;

  np->tf->eax = 0;

  for (i = 0; i < NOFILE; i++)
   if (myproc()->ofile[i])
    np->ofile[i] = filedup(myproc()->ofile[i]);
  np->cwd = idup(myproc()->cwd);

  safestrcpy(np->name, myproc()->name, sizeof(myproc(
  pid = np->pid;
  np->state = RUNNABLE;
  return pid;
}
```

How and when the child runs?!

Recall the scheduler

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);
  }
}
```

switchuvm

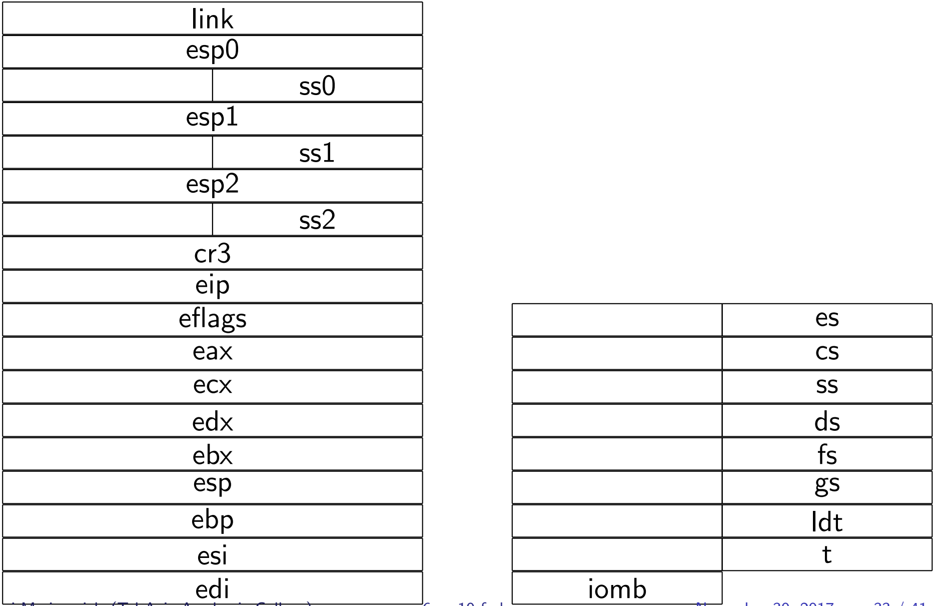
If switching to user mode is expected:

- 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

```
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)

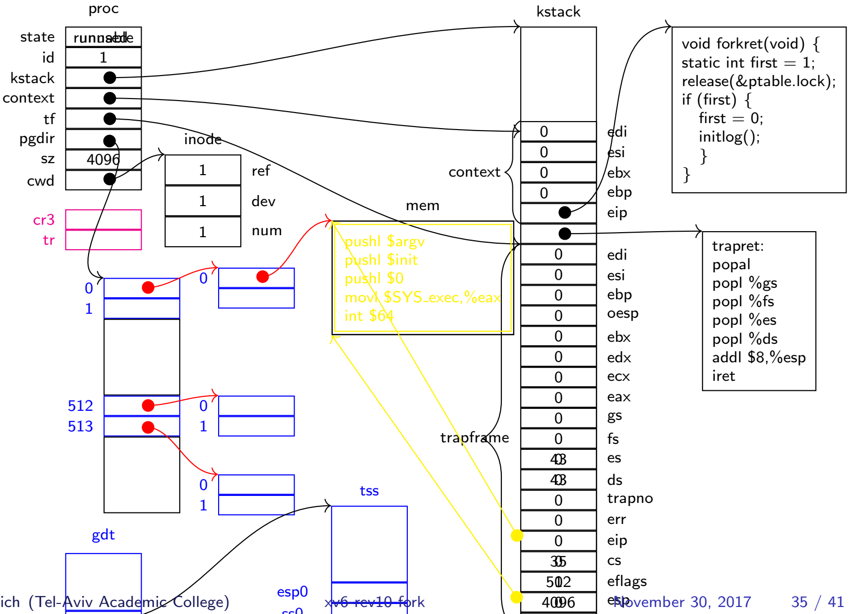


link
esp0
ss0
esp1
ss1
esp2
ss2
cr3
eip
eflags
eax
ecx
edx
ebx
esp
ebp
esi
edi
es
cs
ss
ds
fs
gs
ldt
t
iomb

taskstate in 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



```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
```

```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
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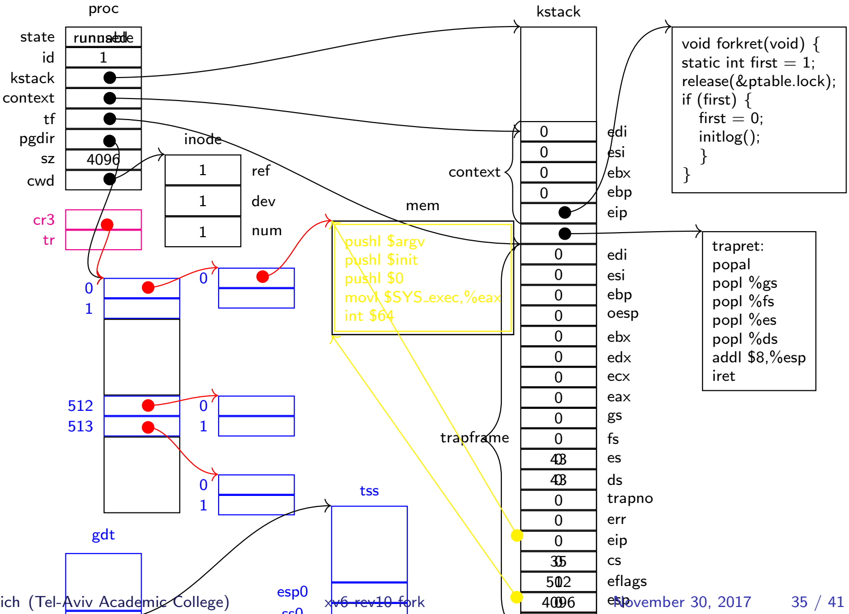
switchuvm



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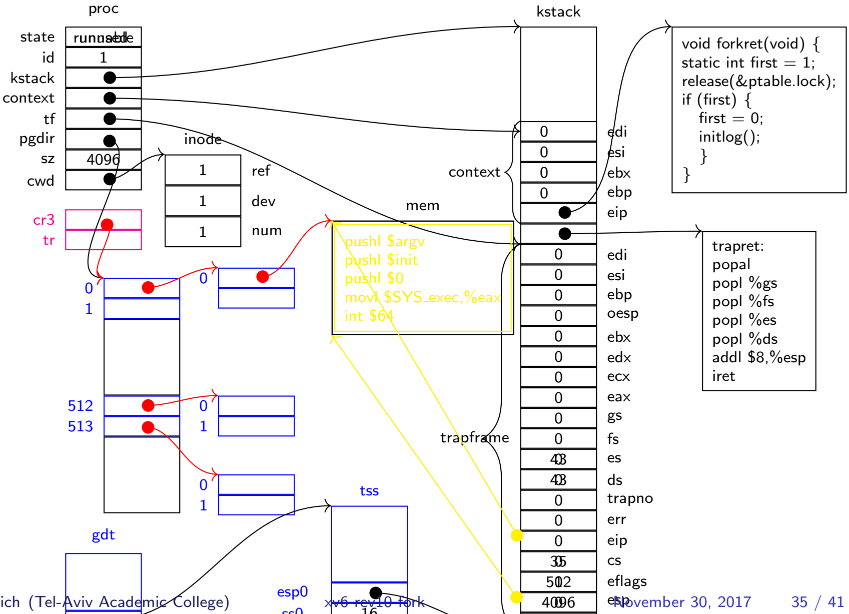
switchuvm



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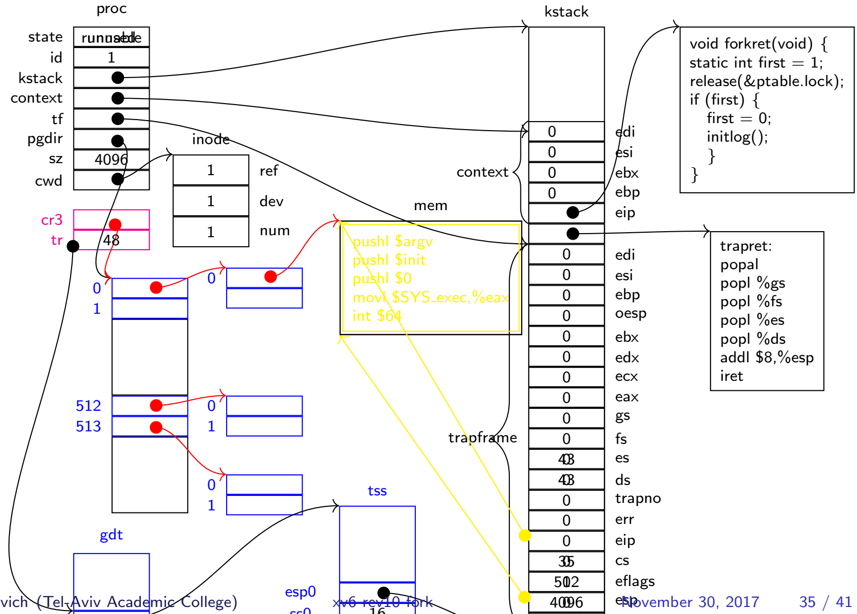
switchuvm



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swtch

co-routines

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

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

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

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

- We have here co-routines.

swtch()

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

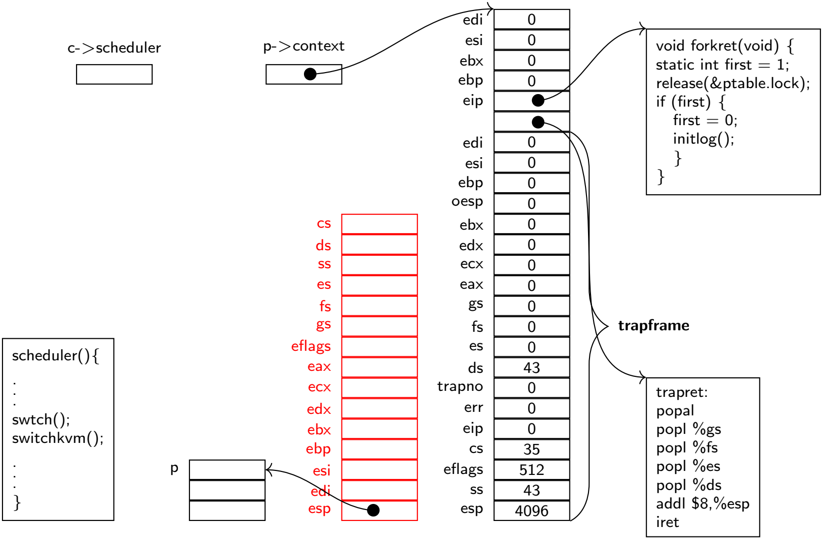
 pushl %ebp
 pushl %ebx
 pushl %esi
 pushl %edi

 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



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   }
}
```

```
trapret:
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popl %gs
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addl $8,%esp
iret
```
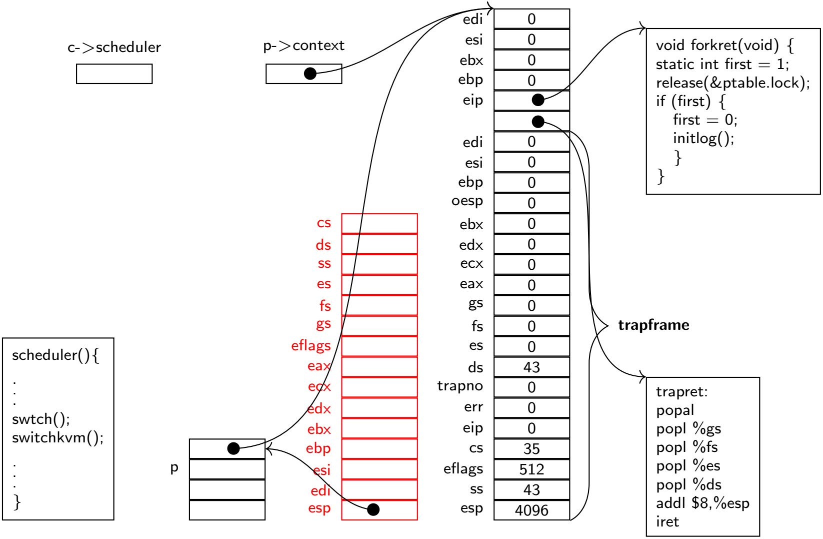

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

swtch() operation



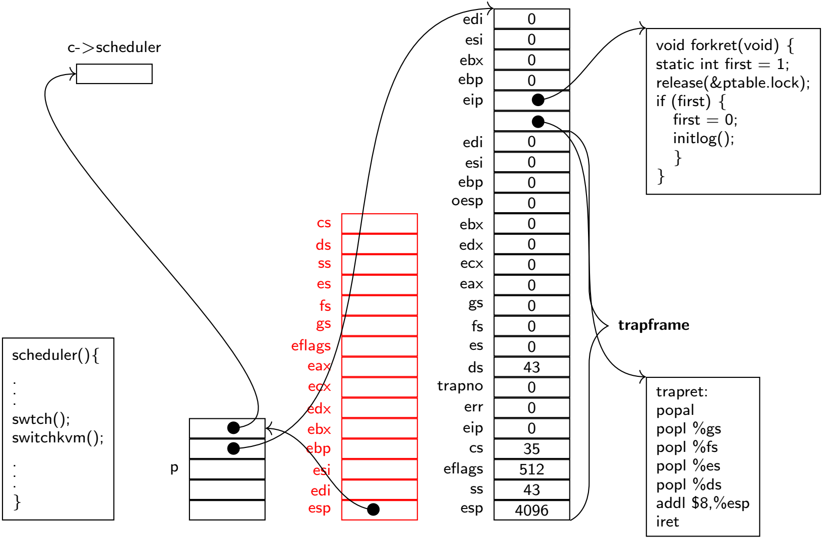
edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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
```

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

swtch() operation



c->scheduler

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

p

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	
ebp	
esi	
edi	
esp	●

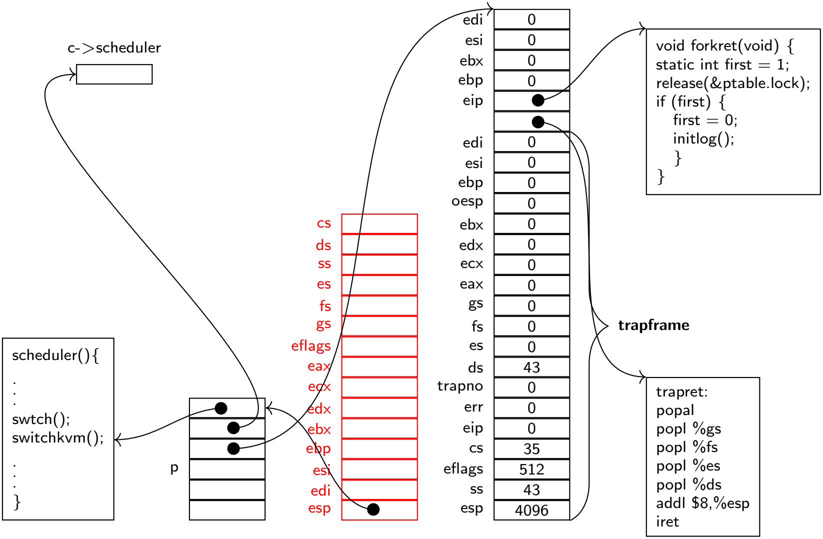
edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

trapframe

```
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
```

swtch() operation



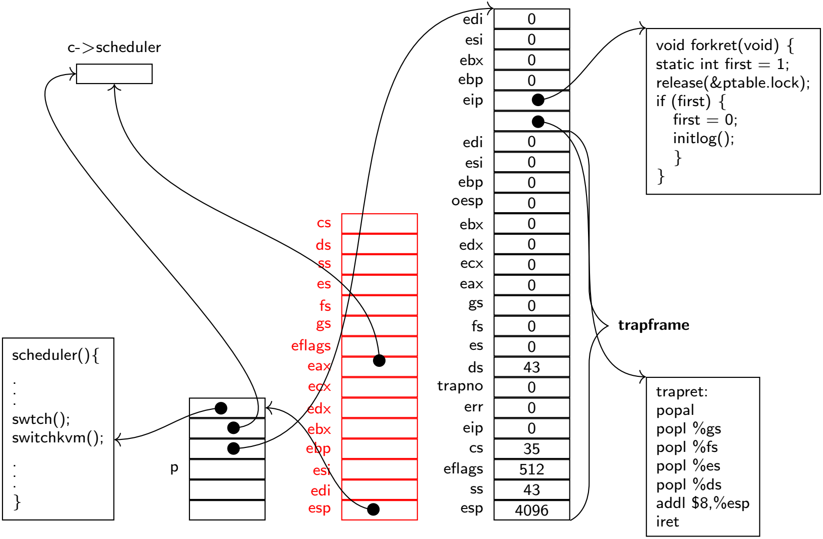
```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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
```

swtch() operation

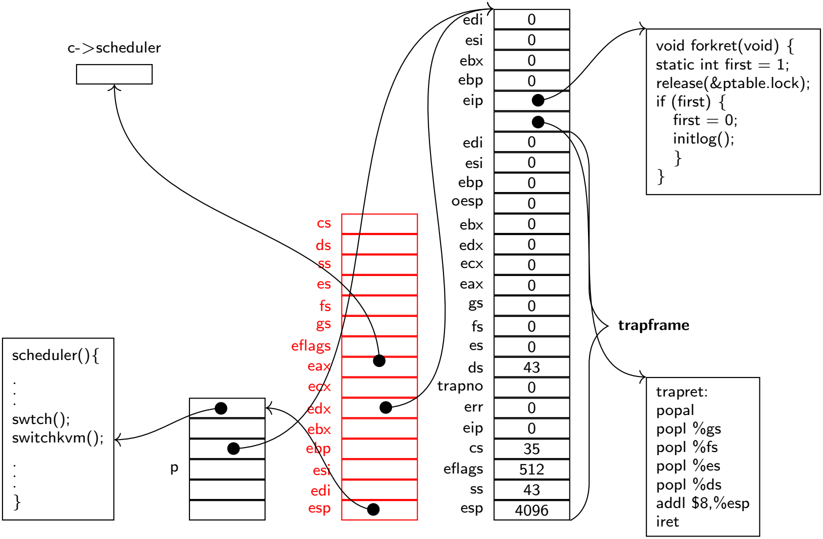


```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
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
```

swtch() operation



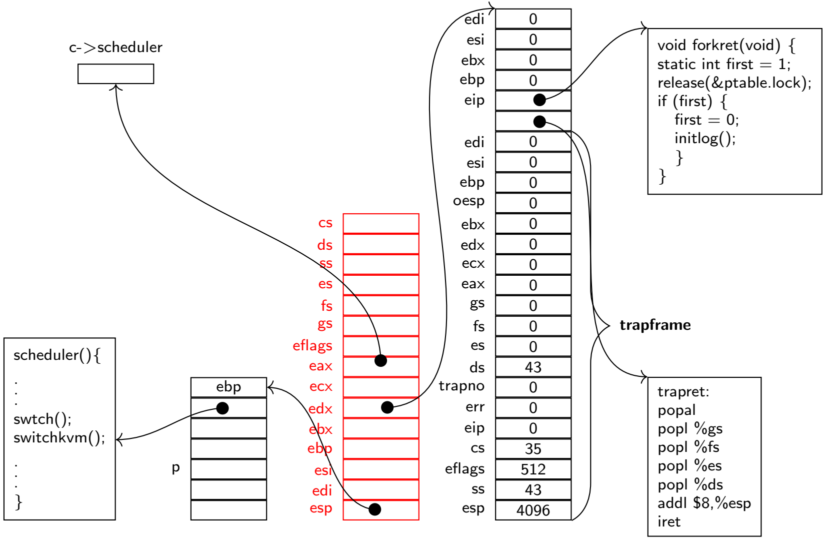
```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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
```

swtch() operation



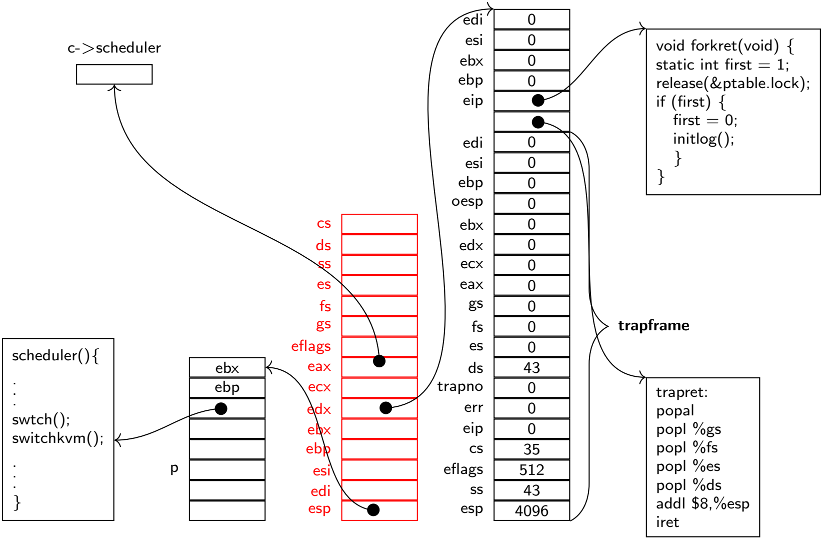
edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
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
```

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

	ebx
	ebp
	●
p	

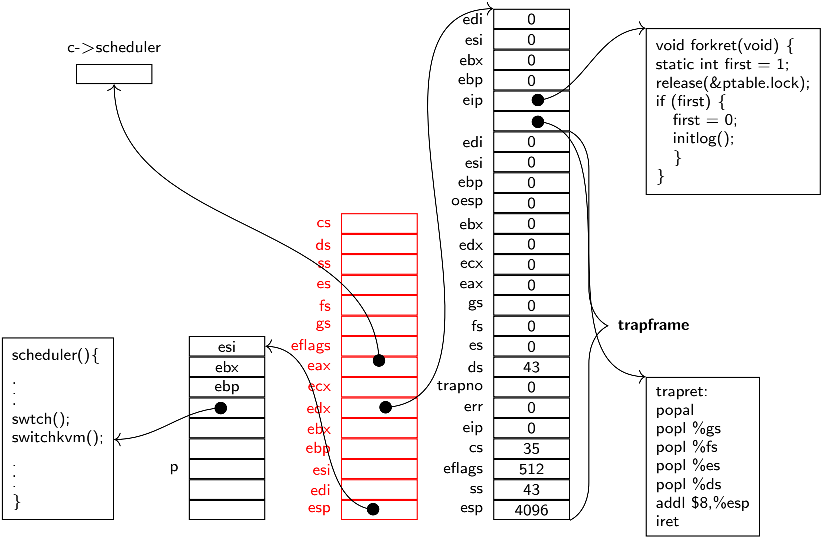
cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	●
ecx	
edx	●
ebx	
ebp	
esi	
edi	
esp	●

edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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
```

swtch() operation



c->scheduler

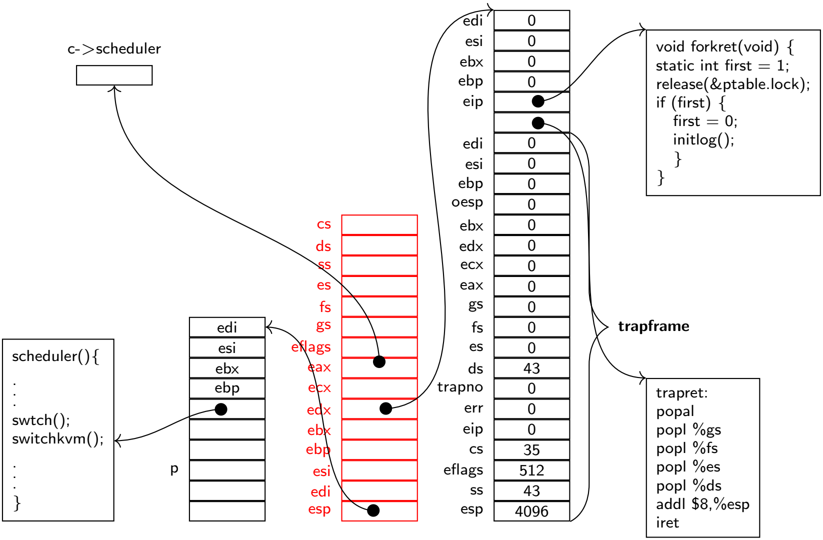
```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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
```

swtch() operation

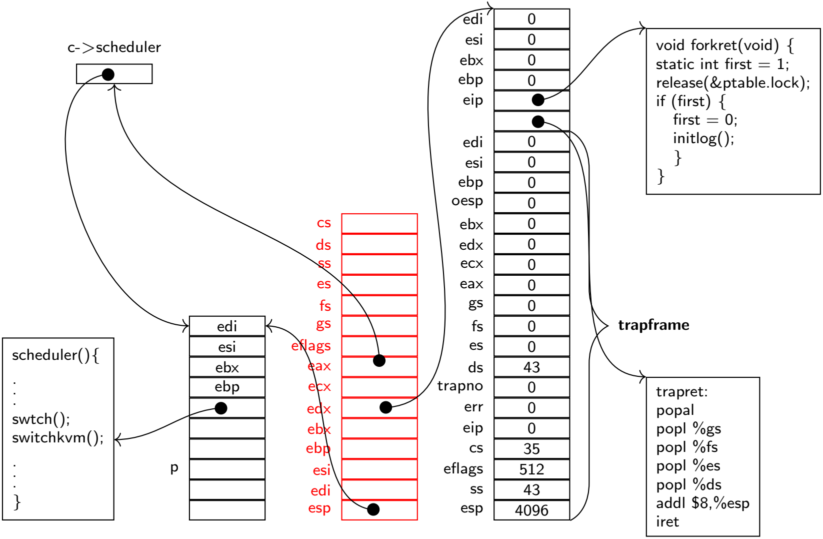


```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
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
```

swtch() operation



c->scheduler

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

	edi
	esi
	ebx
	ebp
	●
p	

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	●
ecx	
edx	●
ebx	
ebp	
esi	
edi	
esp	●

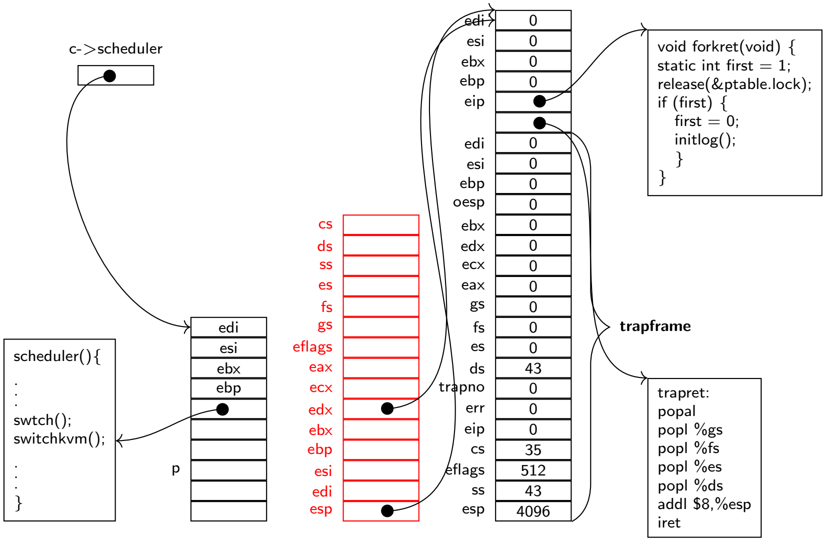
edi	0
esi	0
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

trapframe

```
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
```

swtch() operation

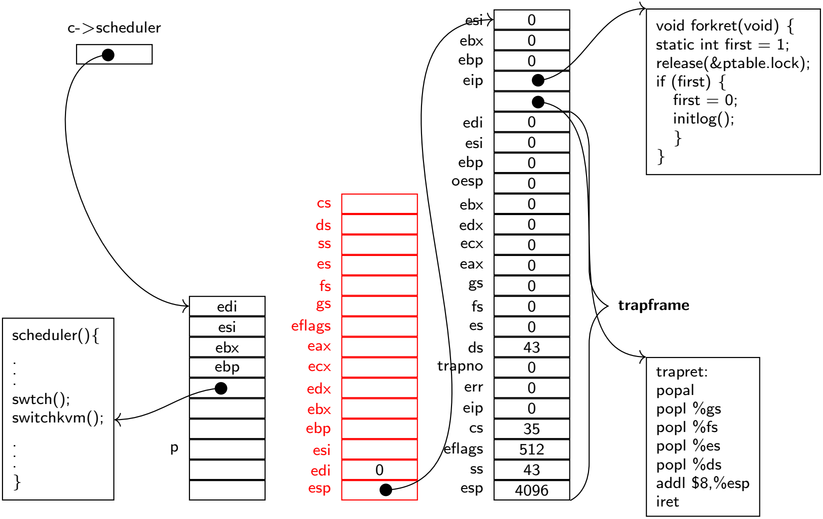


```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
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
```

swtch() operation

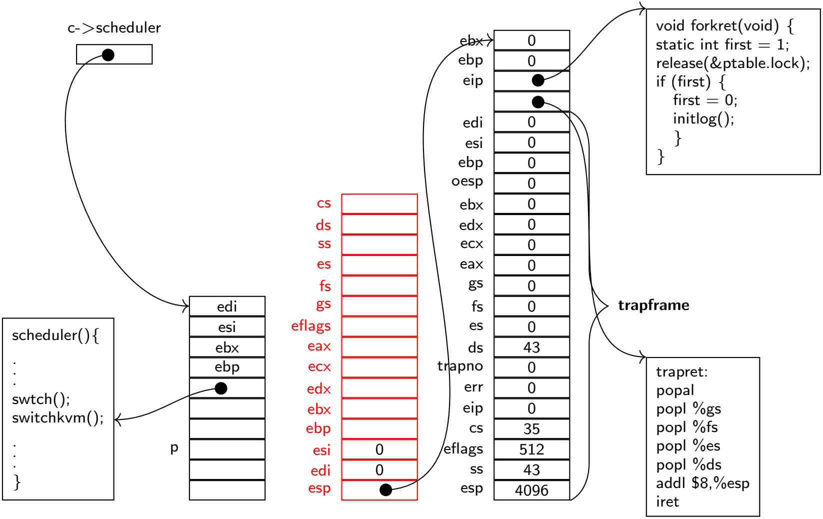


```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
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
```

swtch() operation



c->scheduler

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

	edi
	esi
	ebx
	ebp
	●
p	

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	
ebp	
esi	0
edi	0
esp	●

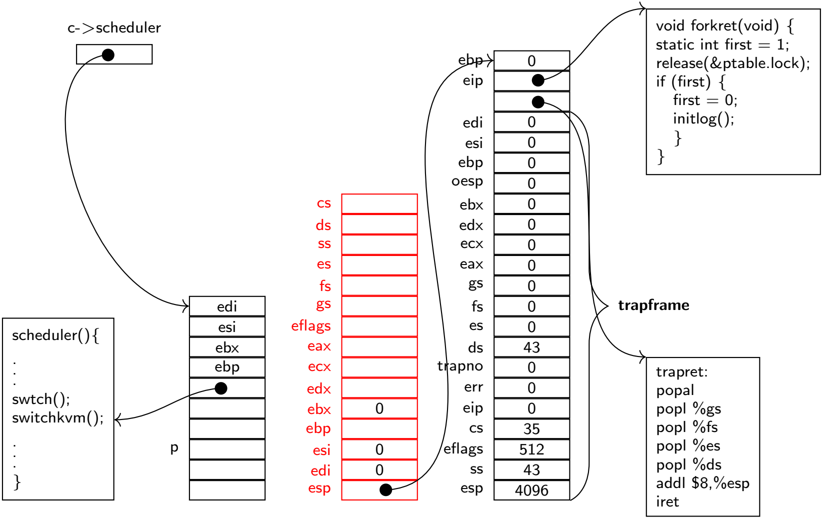
ebx	0
ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

trapframe

```
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
```

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi
esi
ebx
ebp
●
p

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	
esi	0
edi	0
esp	●

ebp	0
eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
void forkret(void) {
static int first = 1;
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if (first) {
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   initlog();
   }
}
```
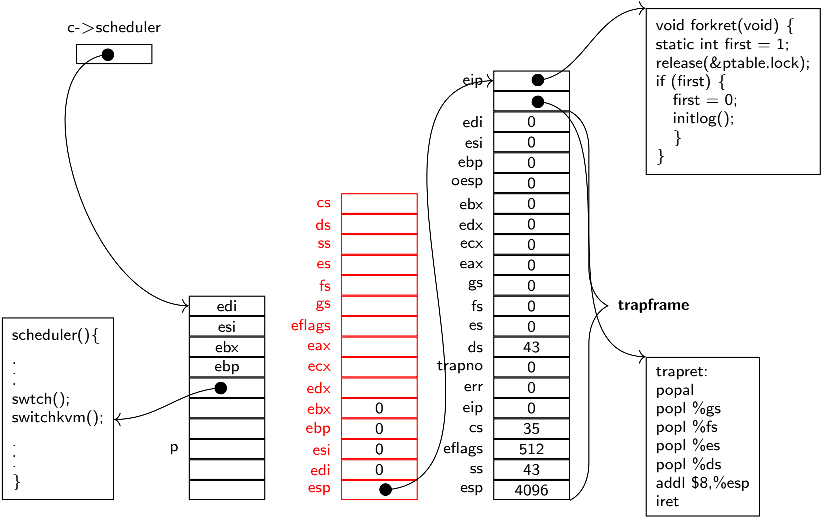

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

```
void forkret(void) {
static int first = 1;
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   initlog();
   }
}
```
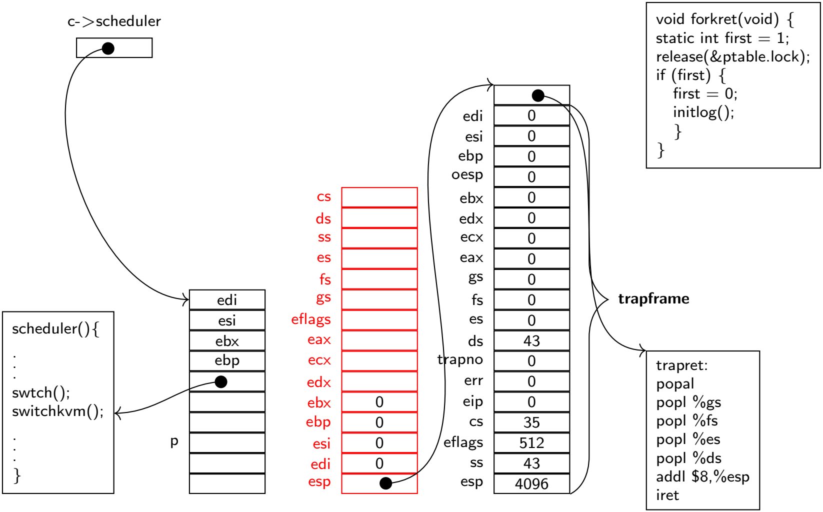

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

eip	●
	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

	●
edi	0
esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
void forkret(void) {
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   first = 0;
   initlog();
   }
}
```
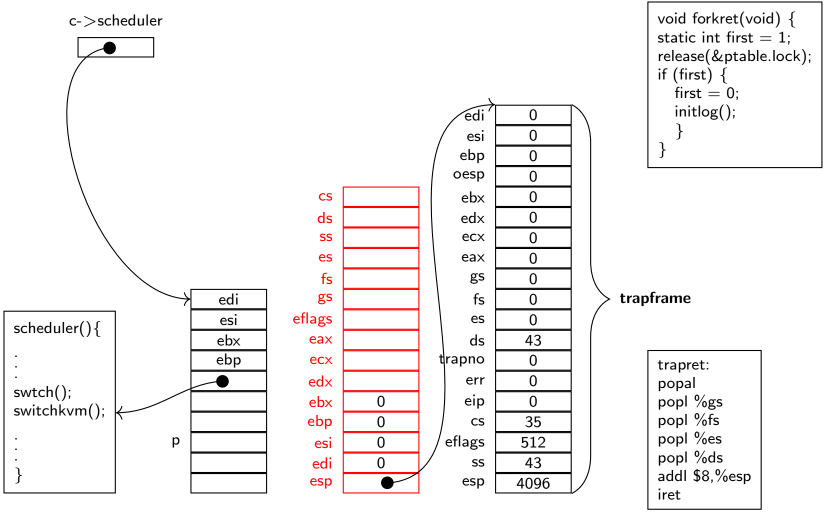

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation



```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
scheduler(){
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.
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swtch();
switchkvm();
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.
}
```
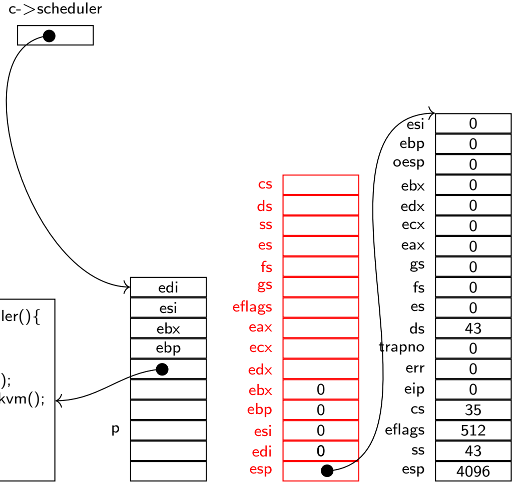

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation



	edi
	esi
	ebx
	ebp
	●
p	

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

esi	0
ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
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   }
}
```

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
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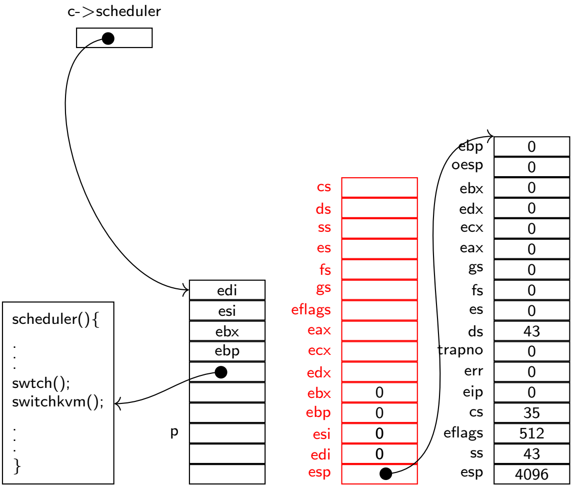
```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi
esi
ebx
ebp
●

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

ebp	0
oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
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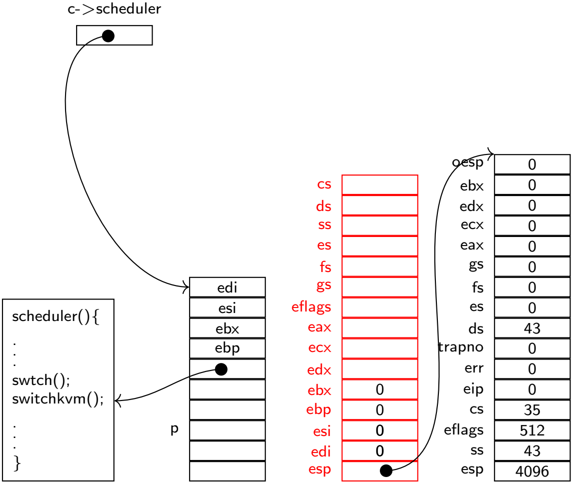
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation

```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```



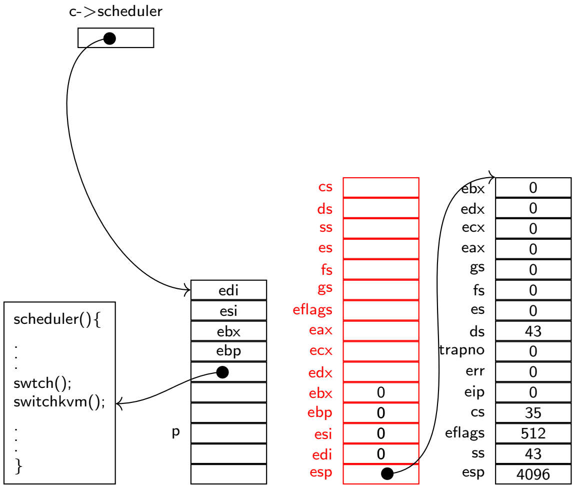
```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

oesp	0
ebx	0
edx	0
ecx	0
eax	0
gs	0
fs	0
es	0
ds	43
trapno	0
err	0
eip	0
cs	35
eflags	512
ss	43
esp	4096

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

swtch() operation



```
scheduler(){
.
.
.
swtch();
switchkvm();
.
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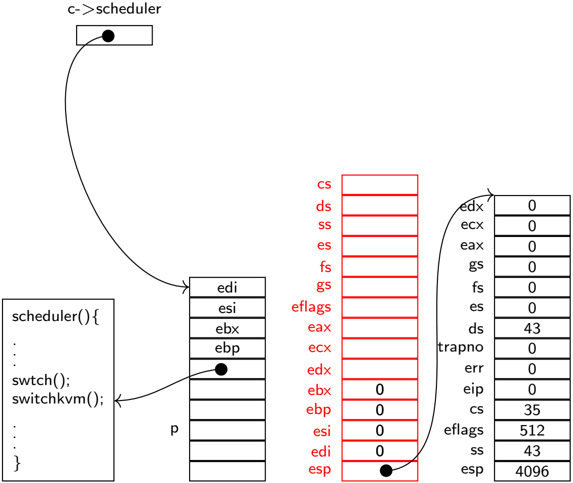

```
scheduler(){
.
.
.
swtch();
switchkvm();
.
.
.
}
```

edi
esi
ebx
ebp
●

cs	
ds	
ss	
es	
fs	
gs	
eflags	
eax	
ecx	
edx	
ebx	0
ebp	0
esi	0
edi	0
esp	●

edx	0
ecx	0
eax	0
gs	0
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ds	43
trapno	0
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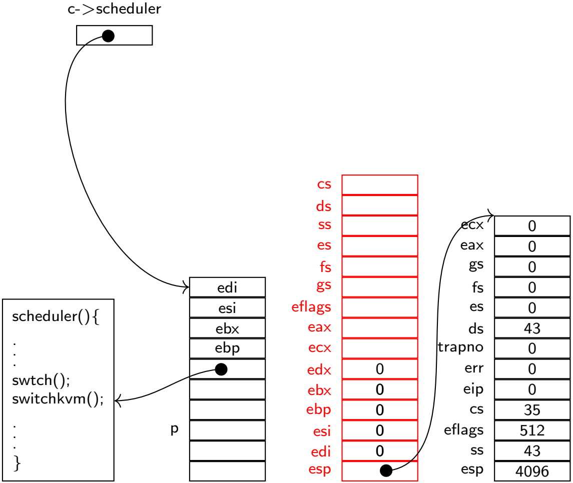

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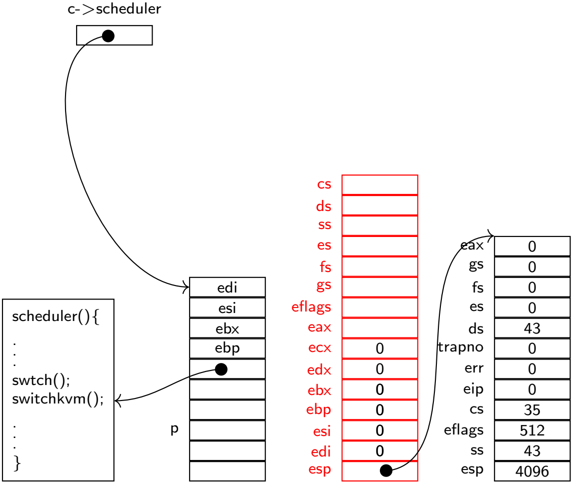

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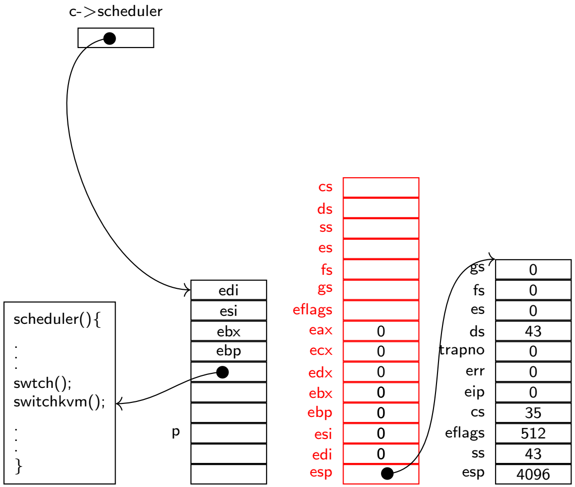

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.
.
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cs	
ds	
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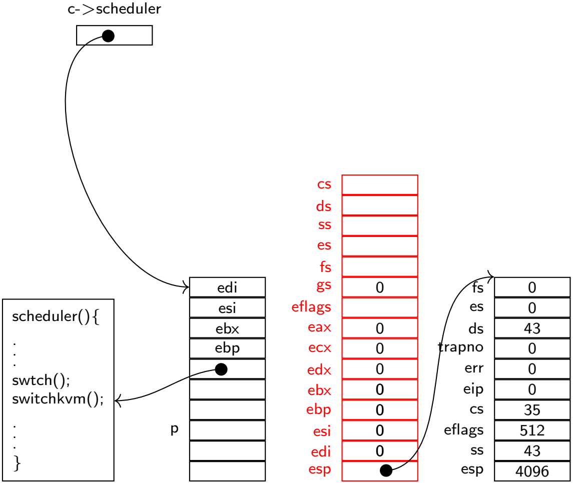

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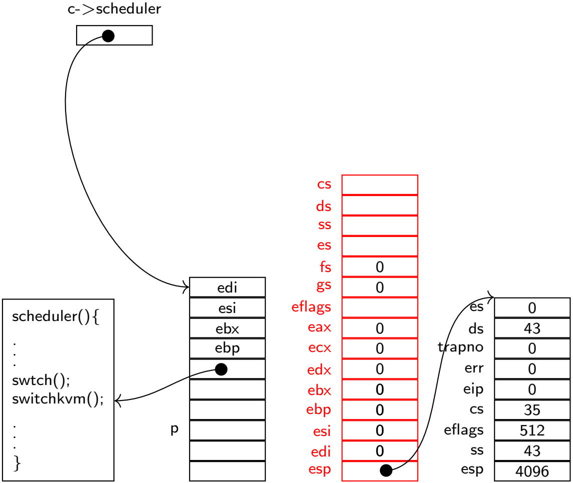

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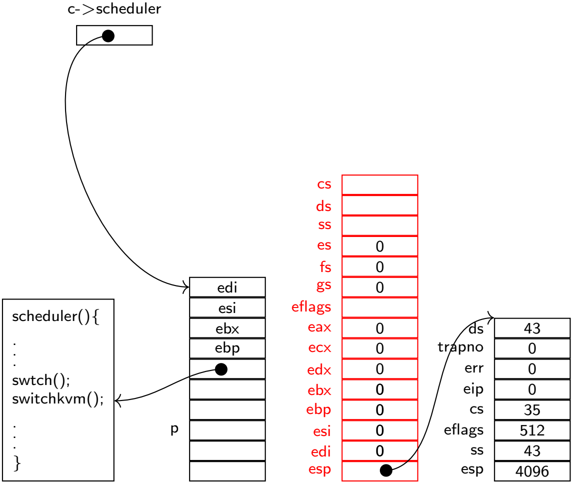

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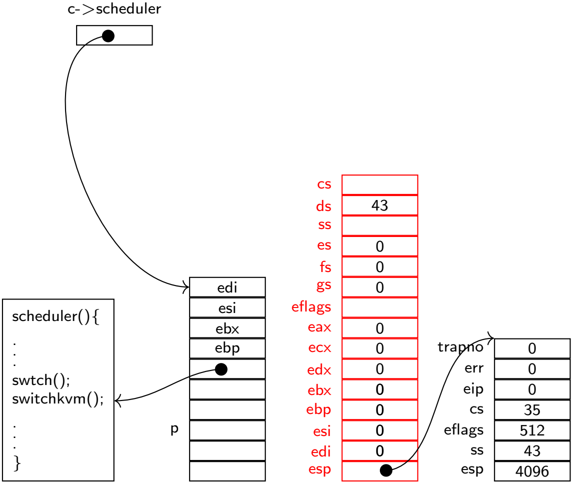

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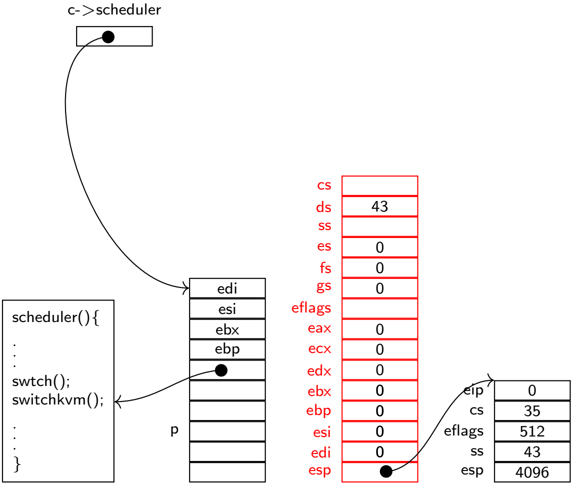

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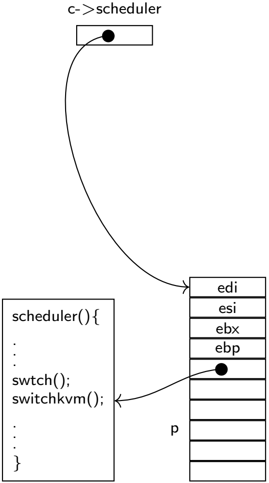

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Context switch

- 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**????

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    - The **gcc** calling conventions deals with them!

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- Where is **gdtr**????

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- 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.