IE 411: Operating Systems

Spinlocks

Recap: Locking

- Locking has two operations:
  - lock(): obtain the right to enter the critical section
  - unlock(): give up the right to be in the critical section
- Note: terminology can vary: acquire/release
- Building a lock needs some help from the hardware

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  - Test & set
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  - Fetch and increment

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  - returns the value stored at `loc` and atomically increments it
- Note that `xchg` is more general than `test-and-set`

A first lock: Spinlock

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  - What will be the outcome?

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- note: a thread busy-waits, or spins, for lock to be released

A first lock: Spinlock

- How do we implement lock release?
  - simply write a 0 to `flag`

Spinlock: XCHG implementation

- pseudo-C code for the `xchg` instruction:

```
int xchg(int *addr, int newval) {
    // start of atomic segment
    int old = *addr;
    *addr = newval;
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  - return what was pointed to by `addr`
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- note: the above code is for illustrative purposes only
  - compiling it will not guarantee atomicity

Spinlock: XCHG implementation

```
typedef struct {
    int flag;
} lock_t;

void init(lock_t *lock) {
    // 0 indicates that lock is available,
    // 1 that it is held
    lock->flag = 0;
}

void lock(lock_t *lock) {
    while (xchg(&lock->flag, 1) == 1)
        ; // spin-wait (do nothing)
}

void unlock(lock_t *lock) {
    lock->flag = 0;
}
```

Evaluating our spinlock

- Desirable properties
  - Mutual exclusion: only one thread can acquire lock at a time
  - Progress: whenever lock is available some thread will get it
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  - Mutual exclusion: only one thread can acquire lock at a time
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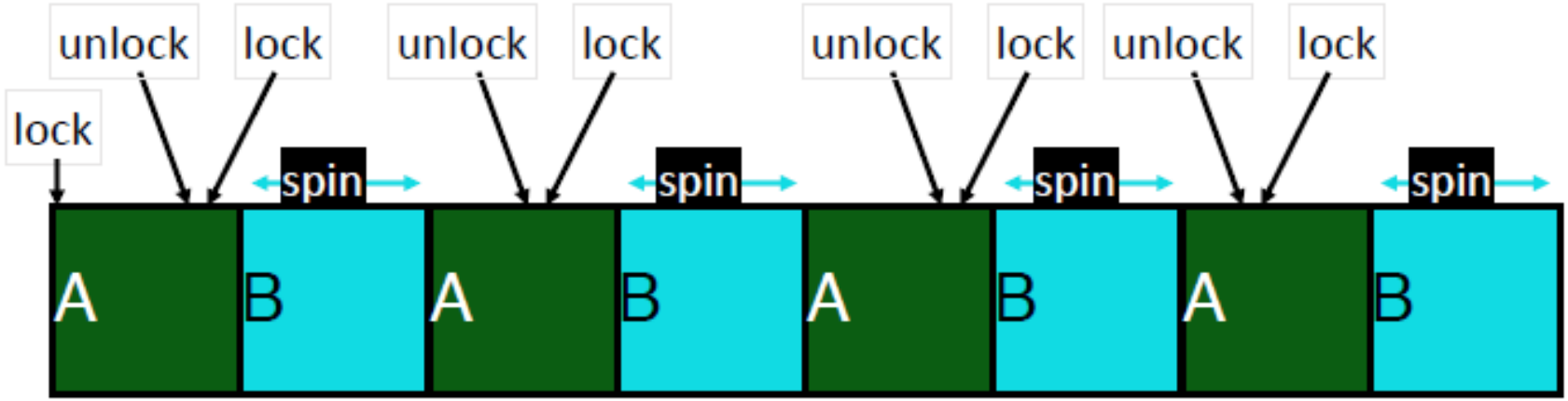
- Which property is NOT satisfied by our lock impl?

Evaluating our spinlock

- Our lock impl does not ensure bounded waiting
  - Thread B may wait indefinitely while thread A repeatedly acquires and releases the lock



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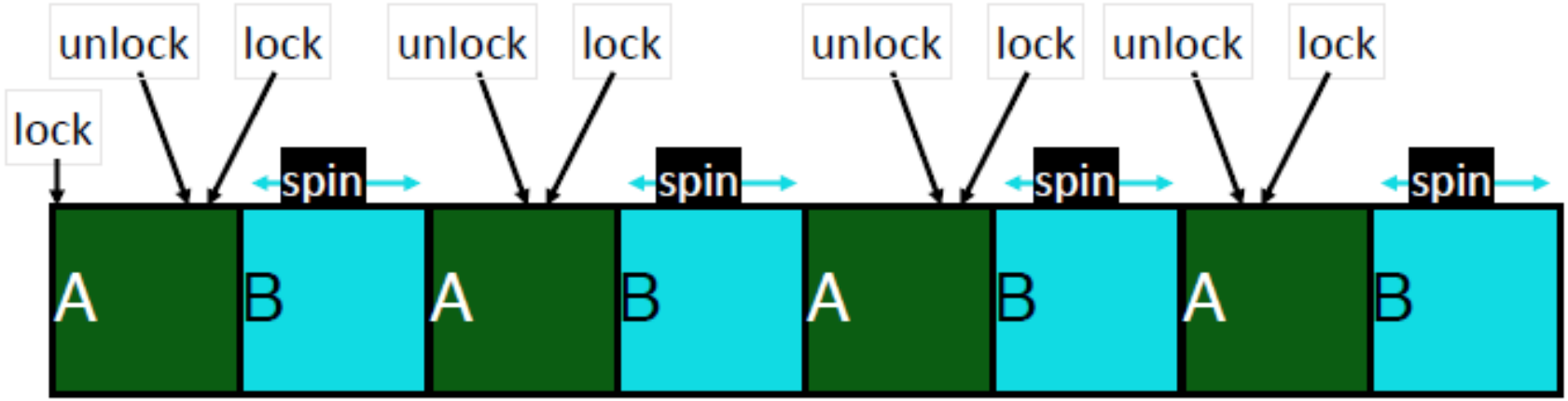

- note: scheduler is ignorant of locks so it may run B instead of A even though B is waiting for a lock that is held by A

Ticket spinlock: waiting for turn

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- On arrival customers draw a ticket from a ticket dispenser which hands out tickets with increasing numbers
- A screen displays the ticket number served next
- The customer holding the ticket with the number currently displayed on the screen is served next

Ticket spinlock: implementation

- Need two variables to hold the lock state
  - `ticket = 0;` // ticket number handed out to the next arriving thread
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  - spin until thread's ticket value is called
- Why atomic increment is necessary?
  - two threads should never get the same ticket

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  - `turn = turn + 1`

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- To release lock, thread that holds the lock increments `turn` by 1
  - `turn = turn + 1`
  - just a normal add operation (non-atomic)

recall: fetch-and-add (atomic increment)

- pseudo-C code for the `fetch-and-add` instruction:

```
int fetch-and-add(int *addr) {
    // start of atomic segment
    int old = *addr;
    *addr = old + 1;
    // end of atomic segment
    return old;
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  - increment the value pointed to by `addr`
  - at the same time, return the previous value

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- note: the above code is for illustrative purposes only
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Ticket spinlock: fetch-and-add implementation

```
typedef struct {
    int ticket; int turn;
} lock_t;

void lock_init(lock_t *lock) {
    lock->ticket = lock->turn = 0;
}

void lock(lock_t *lock) {
    int myturn = fetch-and-add(&lock->ticket);
    while (lock->turn != myturn)
        ;  // spin
}

void unlock(lock_t *lock) {
    lock->turn = lock->turn+1;
}
```

Ticket spinlock example

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	ticket	myturn	turn
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T1 calls lock	1	0	0

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- waiting: waiting for an event, e.g. I/O
  - cannot make progress until event happens

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  - `yield` system call moves calling thread from running to ready state

```
void lock(lock_t *lock) {
    while (xchg(&lock->flag, 1) == 1)
        yield(); // give up the CPU
}
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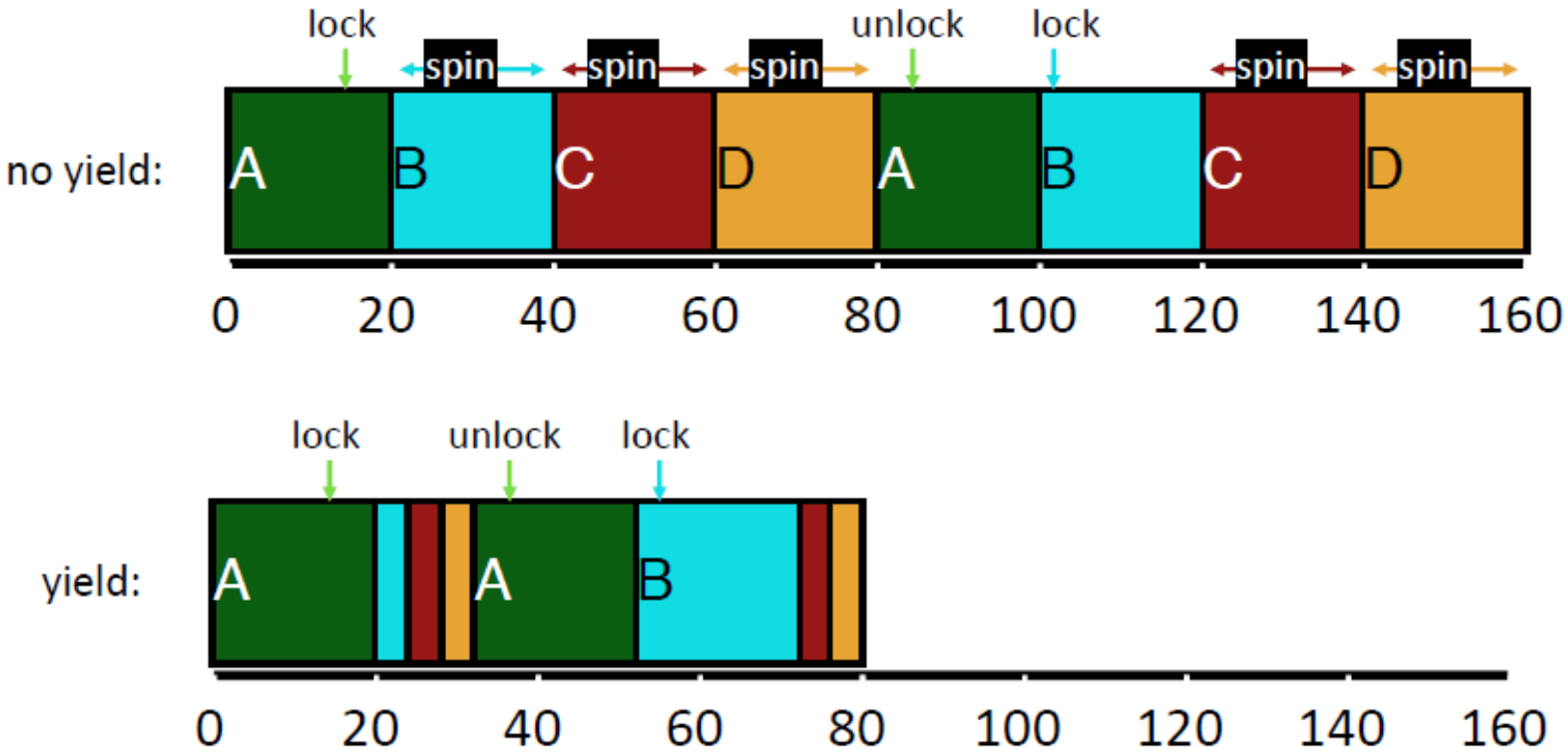
Why is yield() useful?



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- Even with yield, high context switch cost