TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Informatik Institut für Systemarchitektur, Professur für Betriebssysteme

OPERATING-SYSTEM CONSTRUCTION

Material based on slides by Olaf Spinczyk, Universität Osnabrück

Exercise 6: Task #6, Idle Loop, Non-Bl. Thread Sync

https://tud.de/inf/os/studium/vorlesungen/betriebssystembau

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Agenda

- Lab Task #6
- *Idle-Loop, considered harmful*
- Non-Blocking Thread Synchronization

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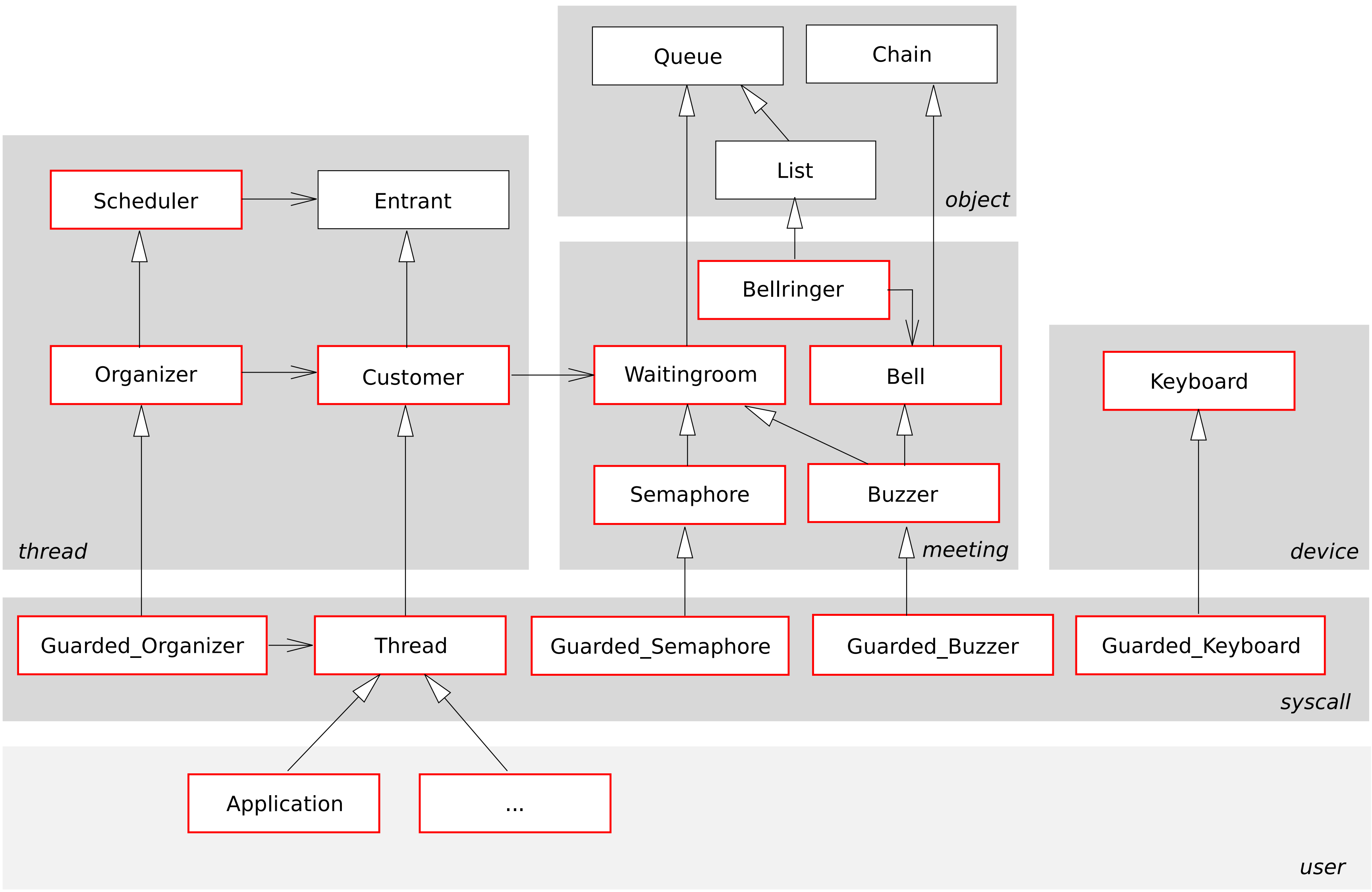
Lab Task #6: The Art of Waiting



Lab Task #6

- `Entrant` → **`Customer`**
  - Can wait for specific events
- Each event is assigned to a **`Waitingroom`**
  - Threads that wait for an event are queued in its `Waitingroom`
  - Synchronization objects are `Waitingrooms` and can trigger events
- `Scheduler` → **`Organizer`**
  - Can **block / "put to sleep"** a thread (*Readylist* → *Waitingroom*)
    - `block(Thread &, Waitingroom &)`
  - and **"wake it up"** again (*Waitingroom* → *Readylist*)
    - `wakeup(Thread &)`
- Events in OOStuBS
  - Semaphore `V()` + and other thread is waiting (in `P()`)
  - A key was added to the keyboard buffer
  - A specific amount of time has passed

Synchronization Object Semaphore

- Derived from **`Waitingroom`**
- **`p()`**
  - If == 0: **Wait** for v() (**wait**)
    - using the `Organizer`
  - Else: decrease by 1
- **`v()`**
  - If a thread is waiting: **Signal the event** (**signal**)
    - Wake up waiting thread
    - What happens if multiple threads are waiting?
  - Else: increase by 1

Synchronization Object Keyboard

- Goal: Use the CPU for other purposes while waiting for I/O
- Thread reads from the keyboard
  - Keyboard driver's `getkey()` returns Keys
  - as long as there are some in the (software) keyboard buffer
  - When keyboard buffer is empty:
    - Thread blocks
    - Waits for event "Keyboard buffer filled again" (**wait**)
  - Signaling of this event (**signal**)
    - Keyboard interrupt
    - Epilogue, due to access from thread level
- Implementation
  - Semaphore that counts keys in the keyboard buffer

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Synchronization Object Buzzer

- **Buzzer**: an alarm clock
  - With `sleep()` threads can block and wait until this alarm clock rings
  - After a period of time specified in `set()`
  - the `ring()` method wakes up waiting threads
- derived from **`Bell`**
  - Has a counter
  - that is counted down with `tick()`
  - and calls `ring()` when run down (`run_down() == true`)
- **`Bellringer`**
  - manages `Bell` objects
  - regularly checks whether they have run down and rings them in this case
- Implementation:
  - without a detour over `Semaphore`
  - directly with `Waitingroom` and `Organizer` (why?)

Synchronization Objects in OOStuBS

- … are part of the kernel state
  - `Keyboard` and `Buzzer` signal events in the epilogue
    - Can we also wait for events in the epilogue?
  - Semaphore (why?)
- … and therefore must reside on the epilogue level
  - `Guarded_Semaphore`
  - `Guarded_Buzzer`
  - `Guarded_Keyboard`

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Idling

- All threads, except one, are waiting for an event.
- Now the last thread also blocks. What now?
  - Busy waiting until one thread is ready again?
    - Definitely makes sure the CPU stays warm …
  - Solution: `cpu.idle()`
    - Runs, like `cpu.halt()`, a **`hlt`** instruction, but enables interrupts before instead of disabling them.
    - When an interrupt occurs, its handler runs, and then the CPU continues execution after the `hlt`.
    - … and then?

```
cpu_idle:
  sti
  hlt
  ret
```

```
while (!(next=readylist.dequeue()))
   cpu.idle();
```

Unfortunately, it's not *that* simple.

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Thread Synchronization: Assumptions

- Threads can be preempted **unpredictably**
  - at any time (also by external events)
    - interrupts
  - by any other thread
    - of higher, same or lower priority (progress guarantee!)
- Typical assumptions for desktop computers
  - *probabilistic*, *interactive*, *preemptive*, *online* CPU scheduling
  - We do not consider other scheduling variants here.

Primarily, **progress guarantee** is causing the trouble here.

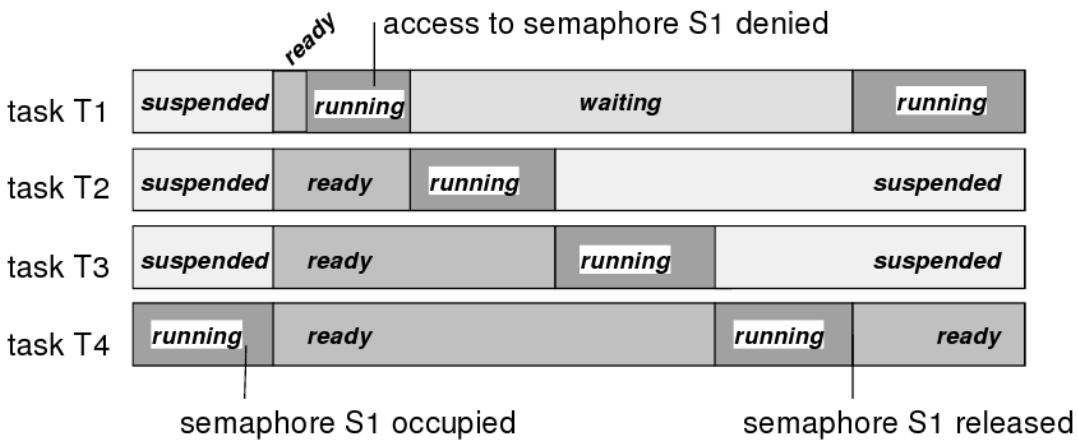
In purely priority-driven systems with sequential thread processing within one priority level, we can simply extend the interrupt-handling control-flow level model to thread priorities, and synchronize with comparable mechanisms (explicit level switch, algorithmic).
(→ event-driven real-time systems)

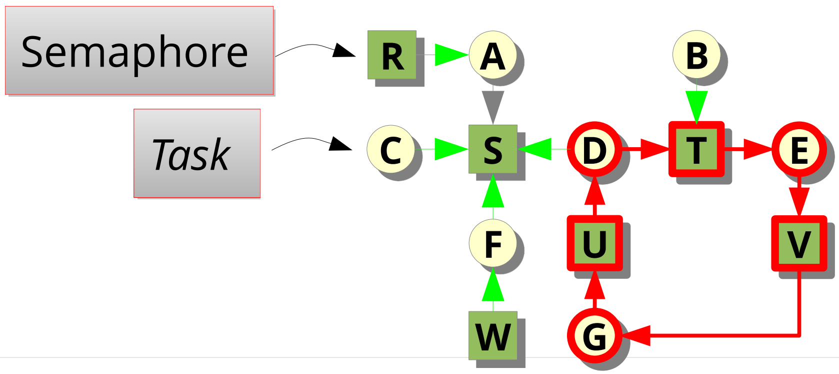
Why all the Fuss with Threads?

- Assume we don't need "progress guarantee"
- Several application levels
  - Instead of threads: one control flow per level
- Do we still need coroutines?
  - What **can't** we do without them?
- Example: OSEK / AUTOSAR-OS
  - Instead of semaphores or mutexes: so-called "resources"
  - Synchronization without blocking

OSEK-OS: *Resource Management* (1)

- Synchronization when accessing shared resources, e.g. global variables, I/O devices, …
- Avoids known issues of semaphores:





Priority Inversion

Because T4 occupies the semaphore, T2 and T3 (which have nothing to do with the semaphore!) indirectly delay the higher-prioritized T1 – because T4 holds the semaphore but cannot continue running yet.

Deadlock

We have a cycle in the resource-allocation graph. None of the involved tasks runs anymore.

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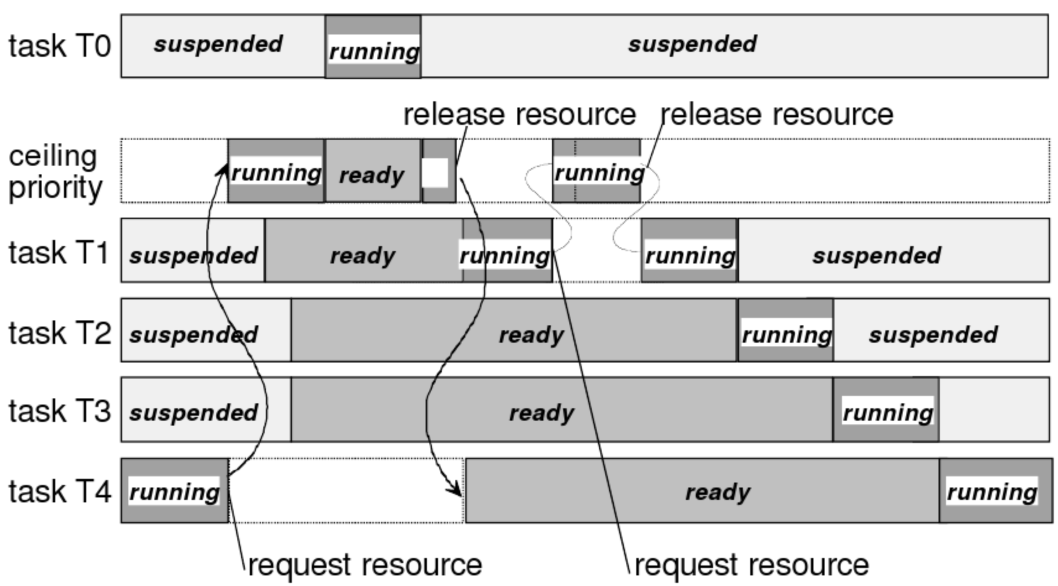
OSEK-OS: *Resource Management* (2)

- The OSEK ***Priority Ceiling Protocol***
  - OSEK statically assigns a **ceiling priority** to each resource: Maximum of the priorities of all tasks that access the resource
  - When a task requests a resource, its priority is raised to the ceiling priority. **Blocking becomes impossible!**
  - After releasing the resource, the original priority is restored.



'GetResource' never blocks. Consequently we cannot run into a deadlock.

As long as T4 occupies the resource, it cannot be preempted by T2 or T3. Therefore we avoid priority inversion.