technische universität dortmund

fakultät für informatik

Embedded and Real-time Operating Systems

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(slides are based on Prof. Dr. Chen and Prof. Dr. Marwedel)

Outline

- Embedded operating systems
  - Characteristics
- Real-time operating systems (RTOS)
  - Definition and requirement
  - Kernels
  - Classes

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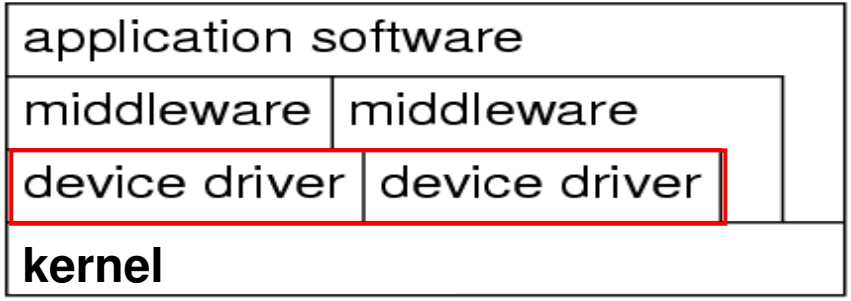
  - **Kernels**
  - **Classes**

Embedded operating systems

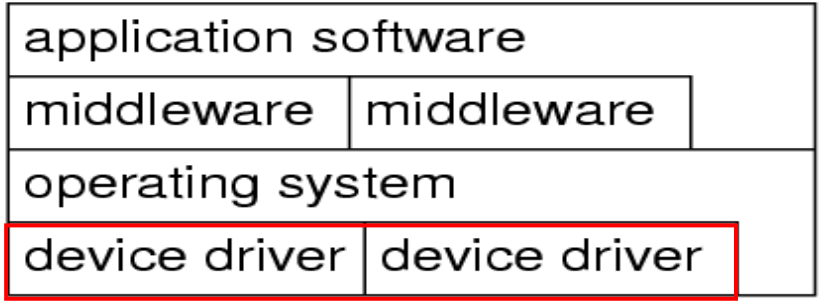
- Characteristics: Disk and network handled by tasks -

- Effectively no device needs to be supported by all variants of the OS, except maybe the system timer.
- Many ES without disk, a keyboard, a screen or a mouse.
- Disk & network handled by tasks instead of integrated drivers.

Embedded OS

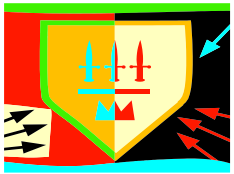


Standard OS



Embedded operating systems
- Characteristics: Protection is optional -

- **Protection mechanisms not always necessary:**
  ES typically designed for a single purpose, untested programs rarely loaded, SW considered reliable.
- ***Privileged* I/O instructions not necessary and tasks can do their own I/O.**



Example: Let `switch` be the address of some switch
Instead of OS call, simply use:


```
load register,switch
```

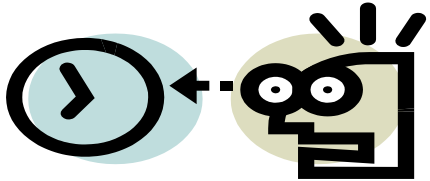
- **<u>However, protection mechanisms may be needed for safety and security reasons.</u>**

Embedded operating systems
- Characteristics: Interrupts not restricted to OS -

- Interrupts can be employed by any process
  - Embedded programs can be considered to be tested
  - Since protection is not always necessary
  - Since efficient control over a variety of devices is required
    - More efficient than going through OS services
  - It is possible to let interrupts directly start or stop SW
- For standard OS: serious source of unreliability

Embedded operating systems
- Characteristics: Real-time capability -

Many embedded systems are real-time (RT) systems and, hence, the OSs used in these systems must be real-time operating systems (RTOSs).



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RTOS - Definition and requirement 1: predictability -

Def.: ***(A) real-time operating system is an operating system that supports the construction of real-time systems.***

<u>Key requirements:</u>

1. **The timing behavior of the OS must be predictable.**
   ∀ services of the OS: Upper bound on the execution time!
   RTOSs must be timing-predictable:
   - **(for hard disks:) contiguous files to avoid unpredictable head movements.**

[Takada, 2001]

RTOS - requirement 2: Managing timing -

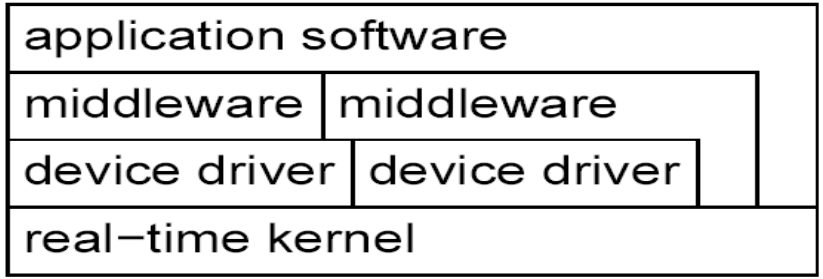
2. OS should manage the timing and scheduling
   - OS possibly has to be aware of task deadlines; (unless scheduling is done off-line).
   - OS should provide precise time services with high resolution.

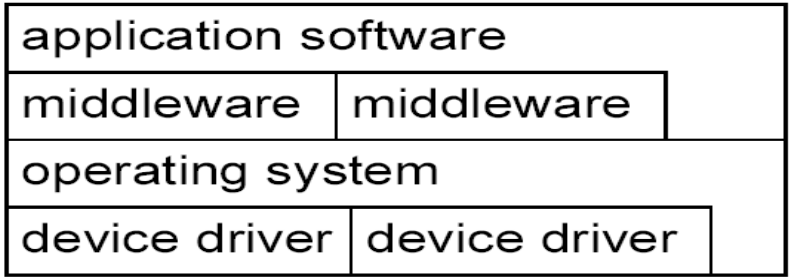
[Takada, 2001]

RTOS-Kernels

Distinction between

- **Real-time kernels and modified kernels of standard OSes.**





Distinction between

- **General RTOSs and RTOSs for specific domains**

Source: R. Gupta, UCSD

Functionality of RTOS-Kernels

Includes

- processor management,
- memory management,
- and timer management;

} resource management

- task management (resume, wait etc),
- inter-task communication and synchronization.

Classes of RTOSs:
1. Fast proprietary kernels

For complex systems, these kernels are inadequate, because they are designed to be fast, rather than to be predictable in every respect

[R. Gupta, UCI/UCSD]

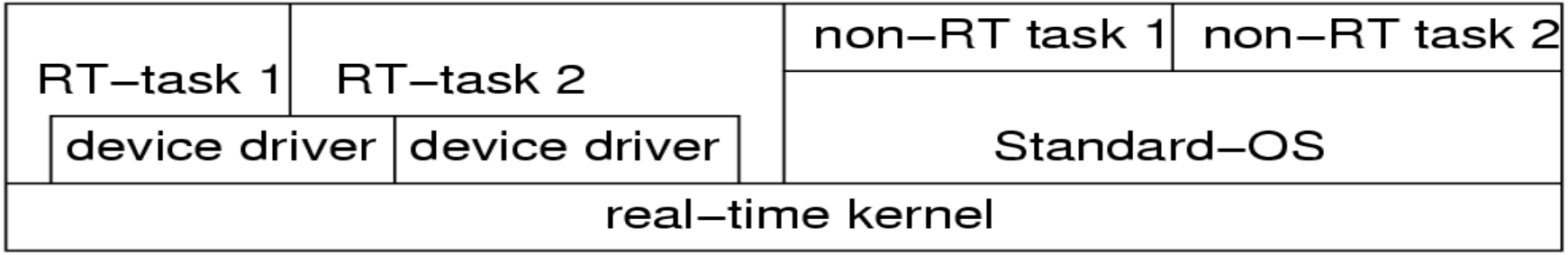
Examples include

QNX, PDOS, VCOS, VTRX32, VxWORKS.

Source: R. Gupta, UCSD

Classes of RTOSs:
2. RT extensions to standard OSs

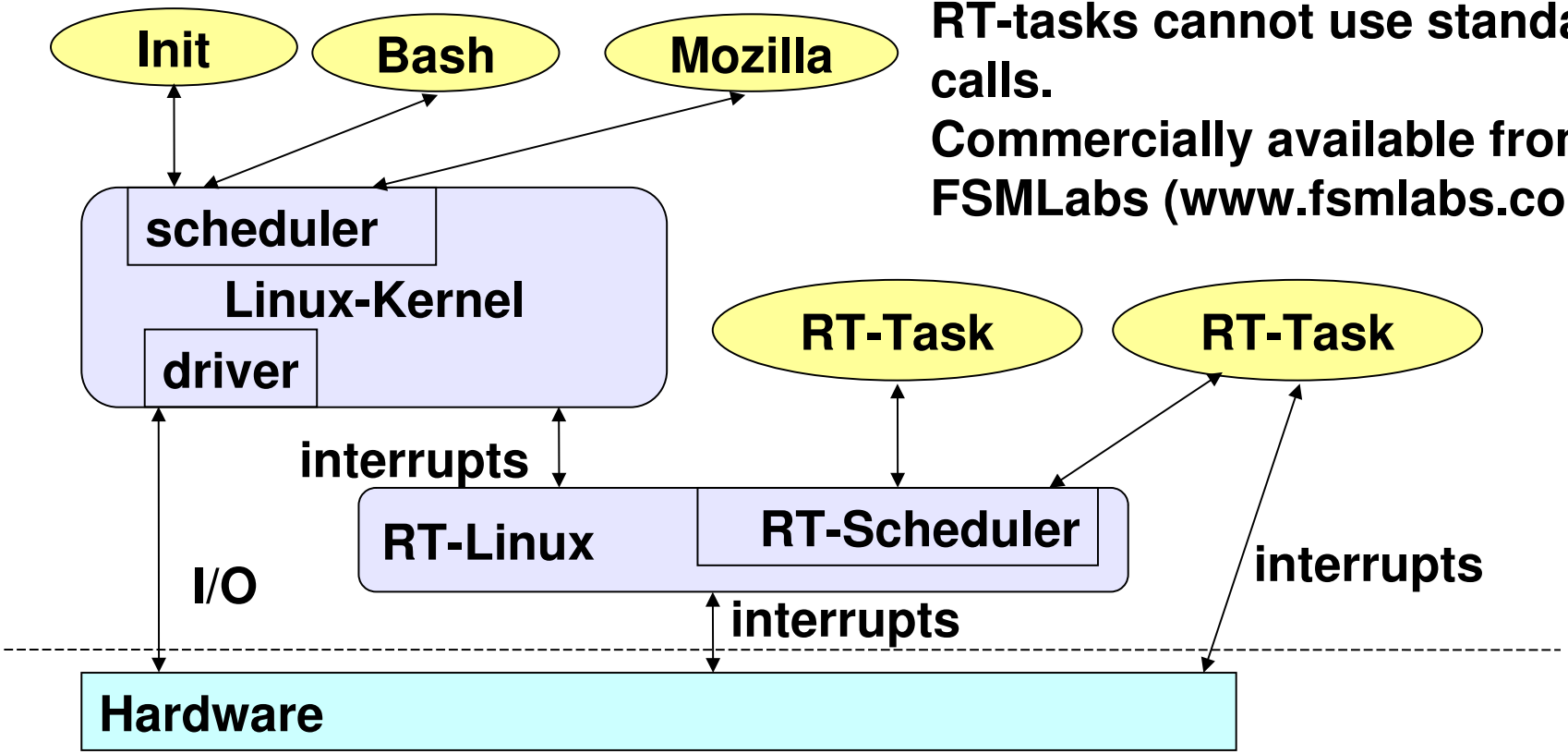
Attempt to exploit comfortable main stream OS
RT-kernel running all RT-tasks
Standard-OS executed as one task



+ Crash of standard-OS does not affect RT-tasks;
– RT-tasks cannot use Standard-OS services; less comfortable than expected

Source: R. Gupta, UCSD

Example: RT-Linux



RT-tasks cannot use standard OS calls.
Commercially available from FSMLabs (www.fsmlabs.com)

Classes of RTOSs:

3. Research trying to avoid limitations

- Research systems trying to avoid limitations.
  - Include MARS, Spring, MARUTI, Arts, Hartos, DARK, and Melody

- Research issues [Takada, 2001]:
  - Low overhead memory protection
  - Temporal protection of computing resources
  - RTOSes for on-chip multiprocessors
  - Quality of service (QoS) control

Source: R. Gupta, UCSD