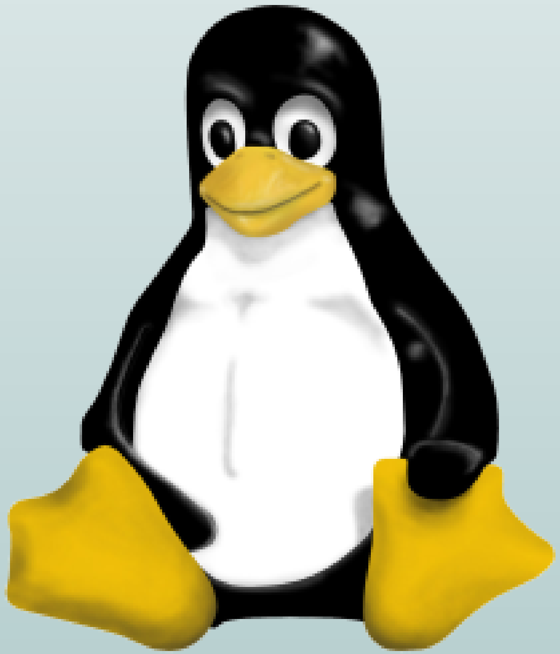
Linux Kernel Hacking Free Course, 3rd edition

R. Gioiosa
University of Rome “Tor Vergata”

Real time systems



March 29, 2006

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- The simplest real time system
- Micro-kernel RTOS
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Real time classification

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Soft real time systems are characterized by their ability to execute a task according to a desired time schedule on the average.

Hard real time systems must always satisfy timing requirements, quality of service, latency constraints, etc.

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Other non-critical processes may be running at the same time: a time-sharing system must reach a compromise between real time and non-real time applications.

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Having an hard real time system is mainly a matter of determinism!

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RTOS must handle problems such as process scheduling, resources allocation, priority inversion, etc.

COTS hardware

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A worse case analysis is required to understand if both hardware and software are *sufficiently real time*.

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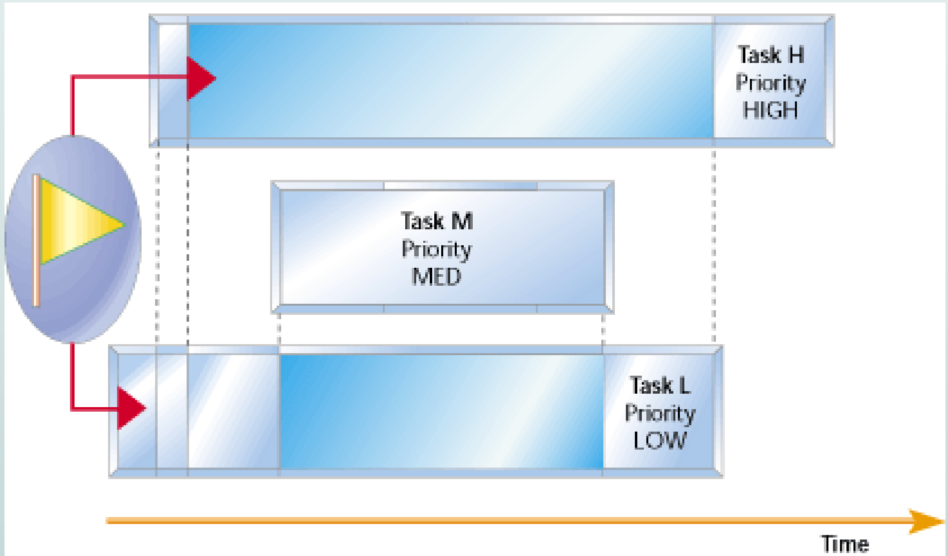

Priority ceiling and priority inheritance avoid this problem. (Do you remember the Mars Pathfinder failure in 1997?)

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Even if this solution seems to be reasonable, in most case the real time application must live with other non-critical applications: somehow an OS support for a multi-tasking environment is required.

RTOS

When OS support is required, there are several approaches:

- micro-kernel (VxWorks, QNX, LynxOS, etc)
- non-micro kernel (RTAI, RTLinux, ASMP Linux, etc.)

Micro-kernel architecture

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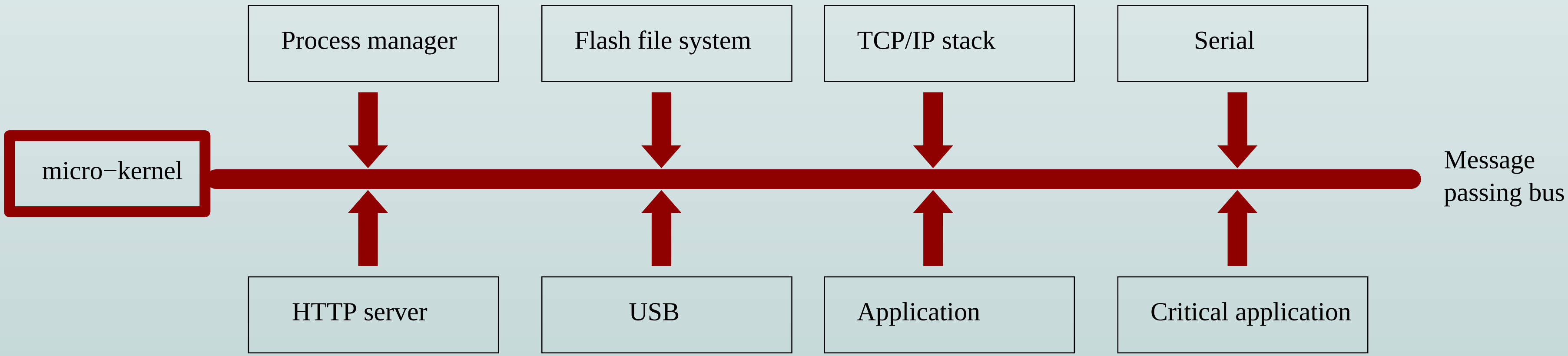

The processes communicate with each other and the hardware by means of a virtual message passing bus.

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Sometimes the MMU is disabled in order to reduce the non-determinism introduced by the TLB, virtual memory, etc. (VxWorks).

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If the MMU is enabled, the hardware already protects data accesses (QNX).

However others resources (hardware caches) are shared and must be invalidated when switching from a process to another.

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- The scheduler is $O(1)$
- A process can have a SCHED_RR of SCHED_FIFO priority
- User processes running in user mode can always be preempted by higher priority processes
- User processes running in kernel mode may also be preempted (kernel preemption)

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The time spent in kernel mode cannot be predicted and the kernel itself cannot be controlled, thus Linux kernel cannot be classified as a hard RTOS.

Handling external events

The main problem for Linux is to handle asynchronous events (such as device interrupts).

Many OSes uses different approaches to solve this problem. We'll consider:

- The Real Time Application Interface (RTAI)
- The Asymmetric Multiprocessor Linux (ASMP Linux)

Adeos (1)

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Each OS runs into a *Domain*:

- interrupts are sent to all domains according to their *domain priority* and availability.
- a scheduler alternates the execution of different domains.

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Because kernels (such as the Linux kernel) cannot be modified in order to remove all the instructions that interacts with the hardware (`cli`, `sti`, etc), the hosted Linux kernel is executed at *ring level 1*.

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Then the Adeos exception handler transforms the Assembly instruction into a logical instruction (`cli` $->$ `stall`).

If a domain is able to talk with Adeos, it can stop the interrupt propagation, so no more domains will receive the interrupt.

Real Time Hardware Abstraction Layer

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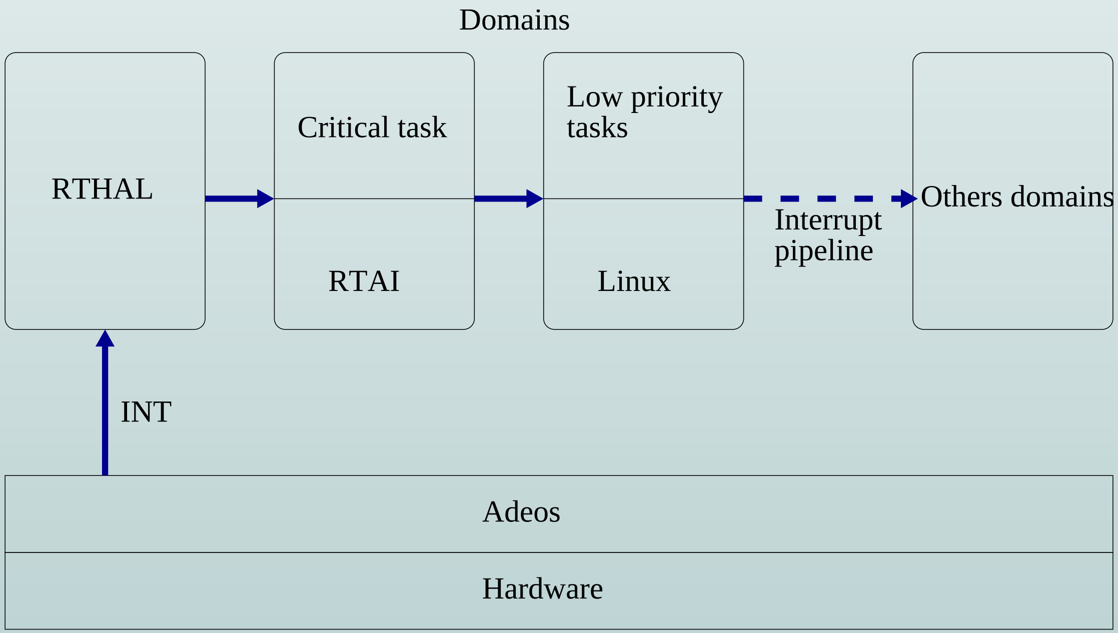

System latency

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- context switch time

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sending a byte along the serial port and getting an answer:

	L. load				H. load			
OS	Avg.	St.dev.	Min	Max	Avg.	St.dev.	Min	Max
Linux 2.6.7	979.83	285.36	568.95	1577.59	1041.25	290.10	568.71	1616.99
RTAI 24.1.13	205.36	3.67	195.58	214.43	205.43	3.68	195.58	219.72
Prop. RTOS	214.72	4.02	203.52	259.29	217.55	11.10	206.14	343.77

SMP Linux

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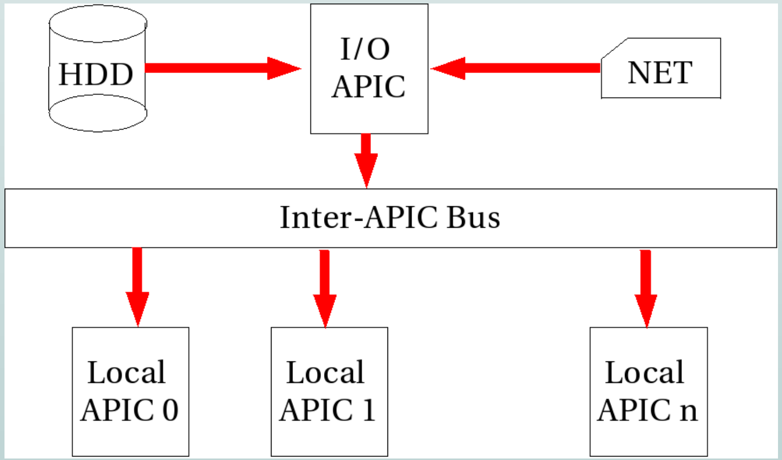
1. Memory symmetric All processors share the same physical memory
2. I/O symmetric Any processors can access the I/O sub-system and handle interrupts



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- Hardware caches of the A-CPU must always be preserved, even if real time applications are sleeping.
- All remaining processes and interrupts must be handled by the others CPUs.

ASMP Linux: advantages

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A device can be associated with the A-CPU realizing a smart device.

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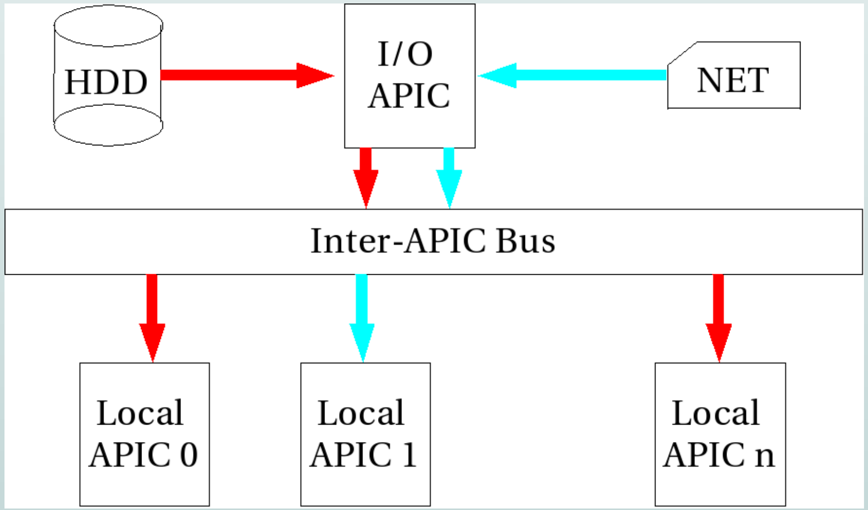

Interrupts coming from the smart device are delivered only to the A-CPU.

ASMP Linux: preliminary tests

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