Real-Time Systems

[Galvin and others]

Real-Time Systems

- System Characteristics
- Features of Real-Time Systems
- Implementing Real-Time Operating Systems
- Real-Time CPU Scheduling
- An Example: VxWorks 5.x

Objectives

- To explain the timing requirements of real-time systems
- To distinguish between hard and soft real-time systems
- To discuss the defining characteristics of real-time systems
- To describe scheduling algorithms for hard real-time systems

Overview of Real-Time Systems

- A real-time system requires that results be produced within a specified deadline period
- An embedded system is a computing device that is part of a larger system (I.e. automobile, airliner)
- A safety-critical system is a real-time system with catastrophic results in case of failure
- A hard real-time system guarantees that real-time tasks be completed within their required deadlines
- A soft real-time system provides priority of real-time tasks over non real-time tasks

System Characteristics

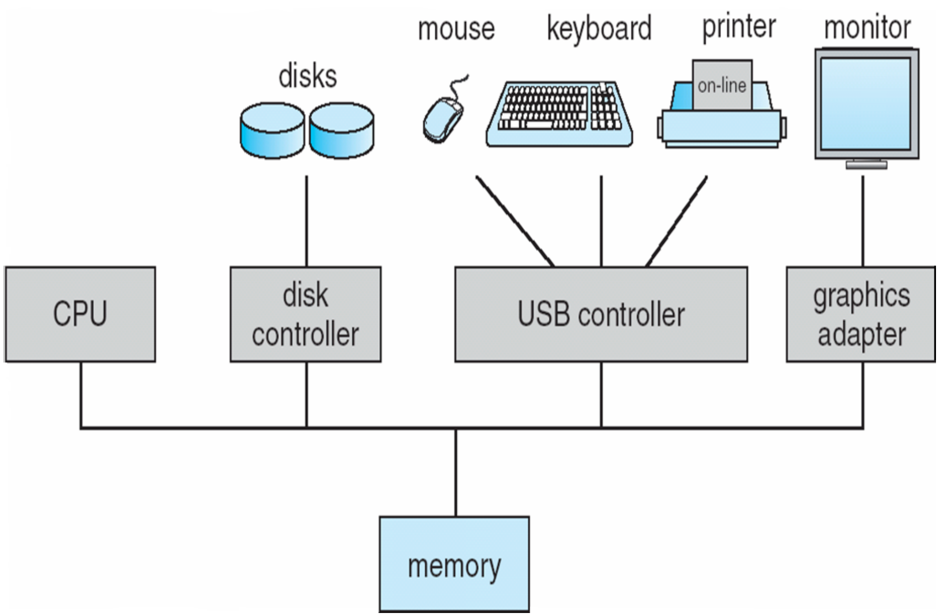
- Single purpose
- Small size
- Inexpensively mass-produced
- Specific timing requirements

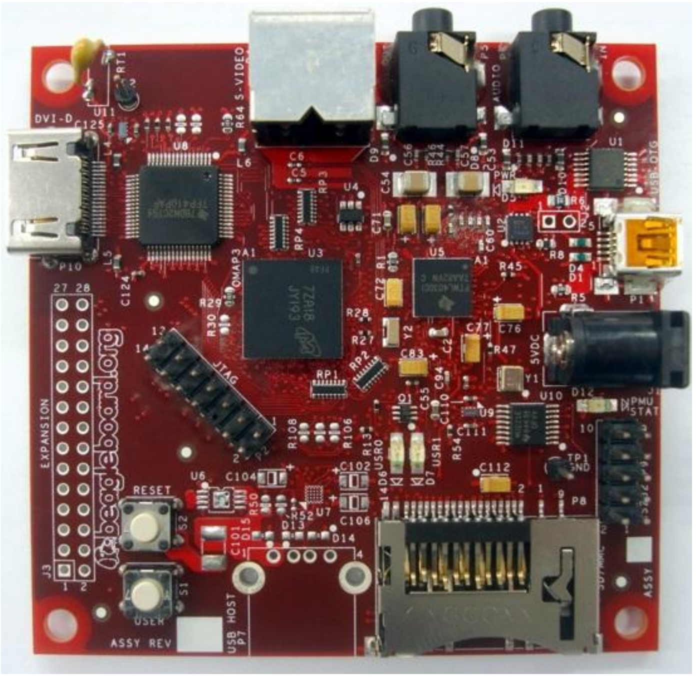
System-on-a-Chip

- Many real-time systems are designed using system-on-a-chip (SOC) strategy

- SOC allows the CPU, memory, memory-management unit, and attached peripheral ports (I.e. USB) to be contained in a single integrated circuit

Bus-Oriented System and System On a Chip (SOC)





Features of Real-Time Kernels

- Most real-time systems do not provide the features found in a standard desktop system
  - Multiuser interface
  - Peripheral Device Support
  - Protection and Security

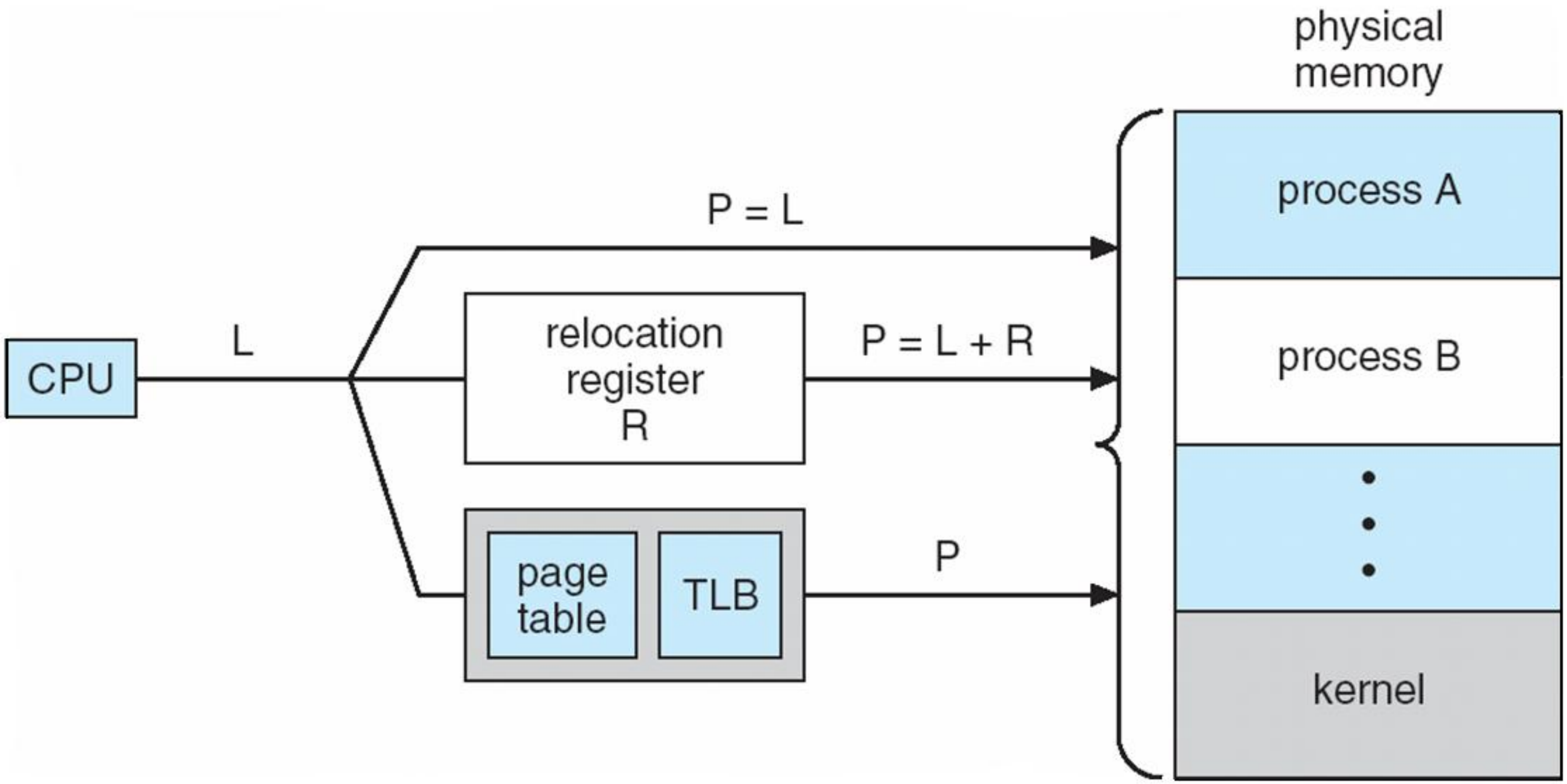
- Reasons include
  - Real-time systems are typically single-purpose
  - Real-time systems often do not require interfacing with a user
  - Features found in a desktop PC require more substantial hardware that what is typically available in a real-time system

Virtual Memory in Real-Time Systems

- Address translation may occur via:

- (1) Real-addressing mode where programs generate actual addresses
- (2) Relocation register mode
- (3) Implementing full virtual memory

Address Translation



Implementing Real-Time Systems

- In general, real-time operating systems must provide:

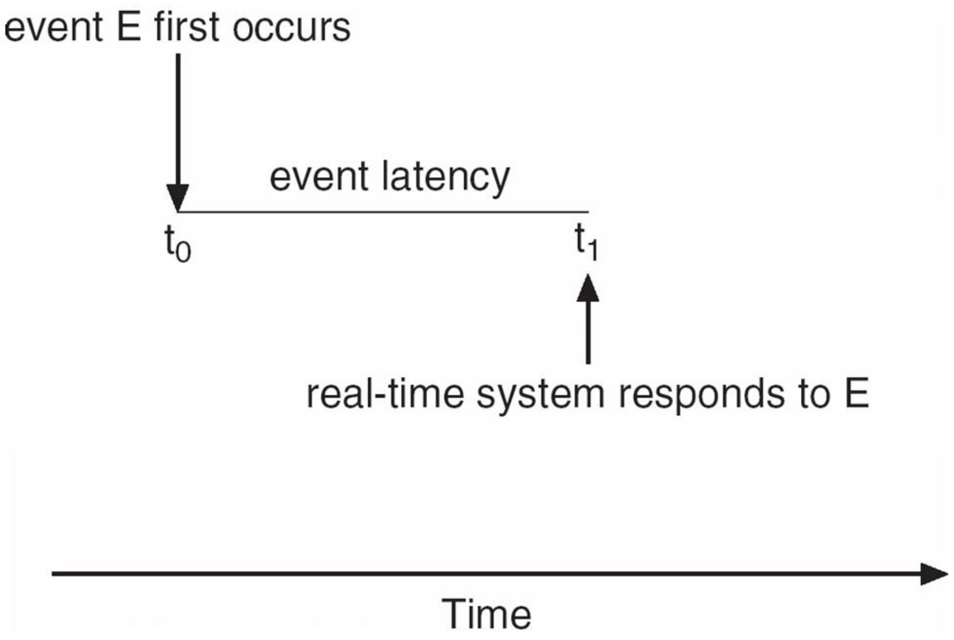
(1) Preemptive, priority-based scheduling

(2) Preemptive kernels

(3) Latency must be minimized

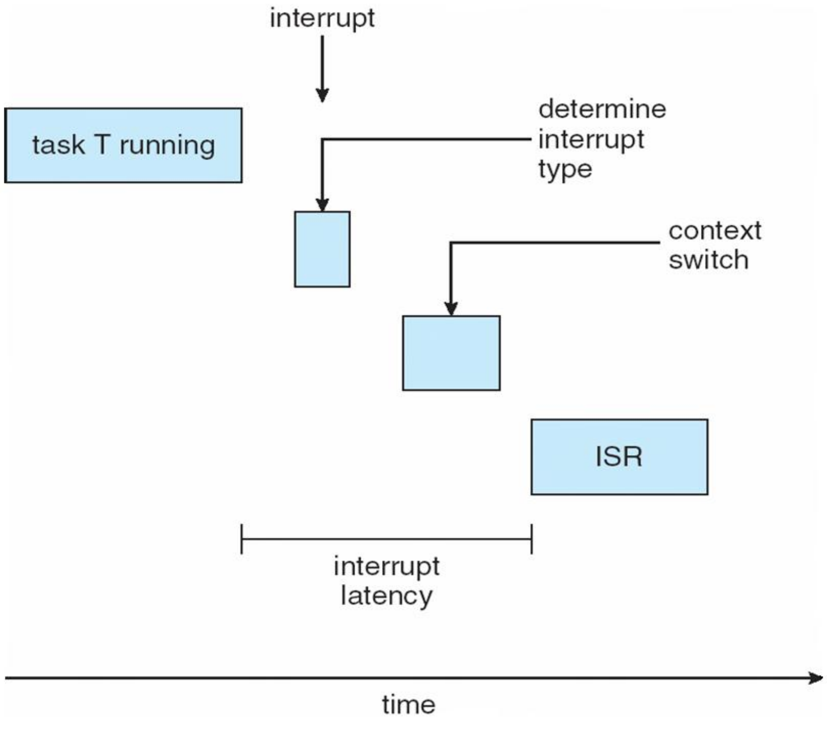
Minimizing Latency

- **Event latency** is the amount of time from when an event occurs to when it is serviced.



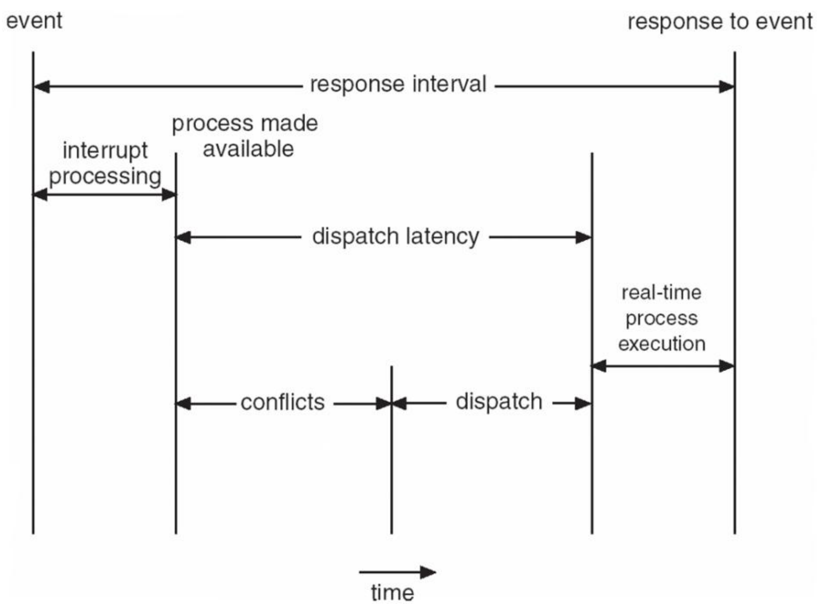
Interrupt Latency

- Interrupt latency is the period of time from when an interrupt arrives at the CPU to when it is serviced



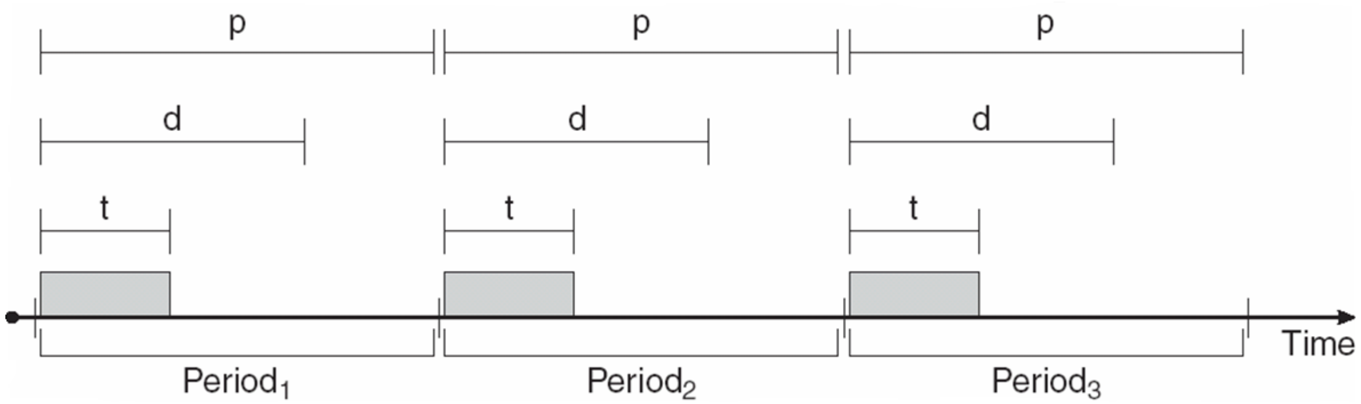
Dispatch Latency

- Dispatch latency is the amount of time required for the scheduler to stop one process and start another



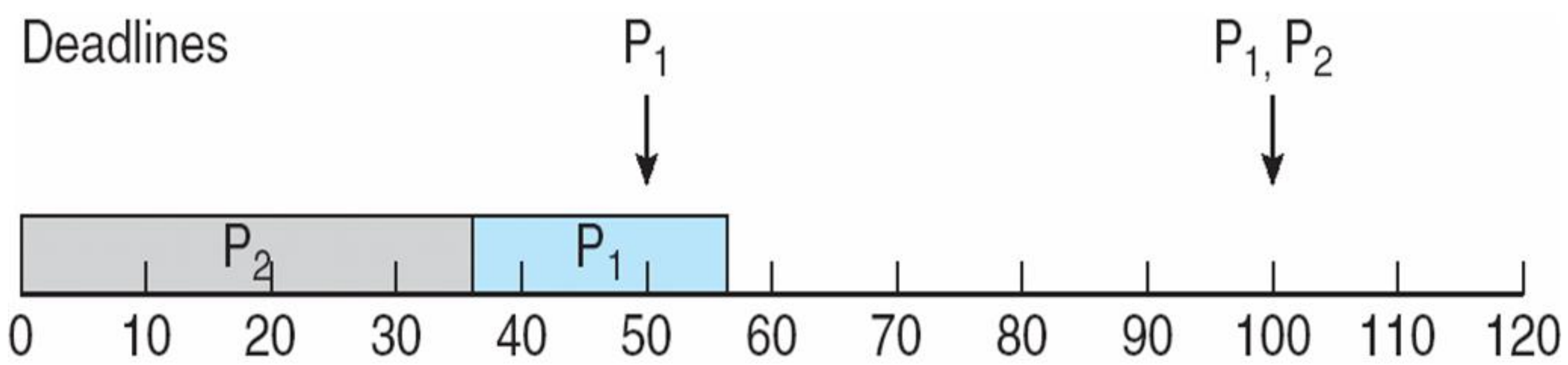
Real-Time CPU Scheduling

- Periodic processes require the CPU at specified intervals (periods)
- ***p*** is the duration of the period
- ***d*** is the deadline by when the process must be serviced
- ***t*** is the processing time



Scheduling of tasks when P_2 has a higher priority than P_1

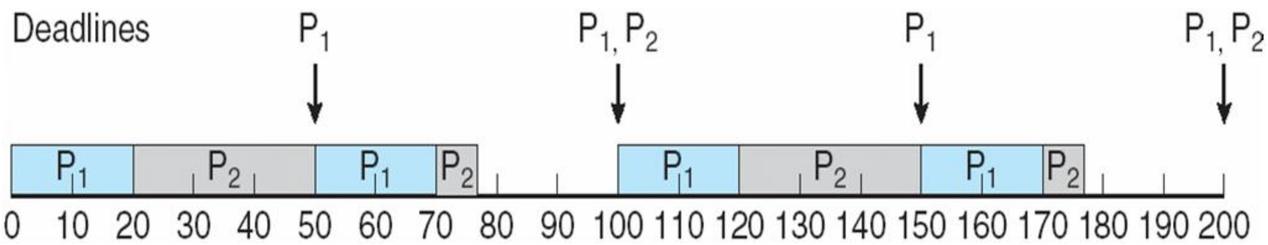
- P1 =50, t1=20
- P2=100, t2=35



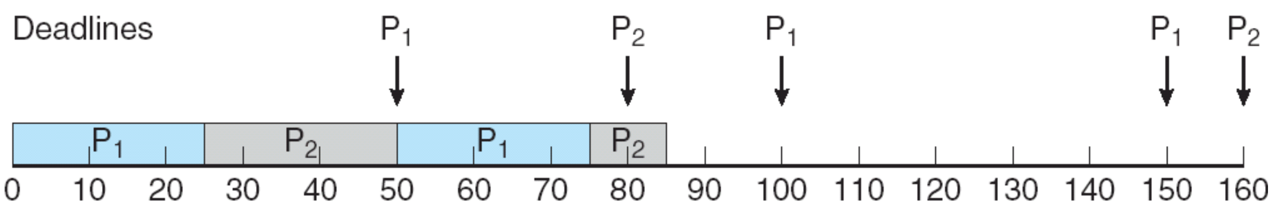
Rate Monotonic Scheduling

- STATIC
- A priority is assigned based on the inverse of its period
- Shorter periods = higher priority;
- Longer periods = lower priority
- P_1 is assigned a higher priority than P_2.

- P1 =50, t1=20
- P2=100, t2=35



- P1 =50, t1=25
- P2=80, t2=35



Missed Deadlines with Rate Monotonic Scheduling

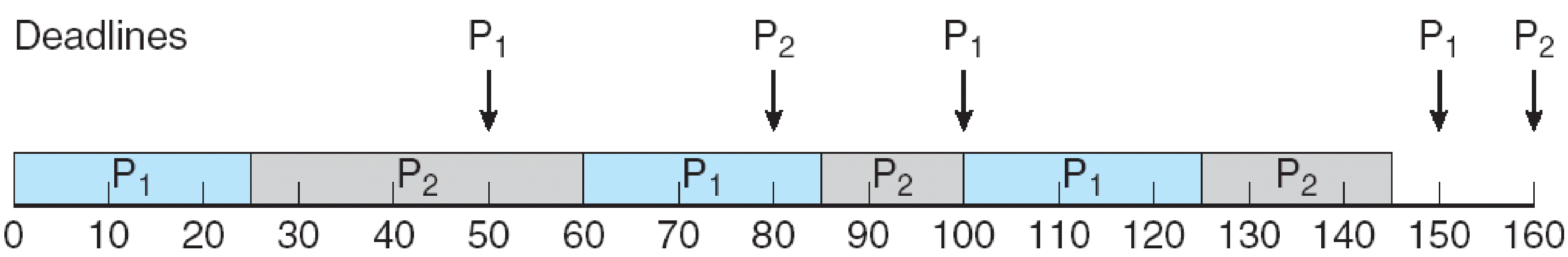
Rate Monotonic Scheduling

- Worst Case Utilization is $2(2^{1/n} - 1)$, n= no. of processes
- If RMS can not schedule a set of given processes then no other static priority scheduling algorithm can schedule them.

Earliest Deadline First Scheduling

- Priorities are assigned DYNAMICALLY according to deadlines:
- the earlier the deadline, the higher the priority
- the later the deadline, the lower the priority

- P1 =50, t1=25
- P2=80, t2=35



Proportional Share Scheduling

- ***T*** shares are allocated among all processes in the system
- An application receives ***N*** shares where ***N* < *T***
- This ensures each application will receive ***N / T*** of the total processor time

Pthread Scheduling

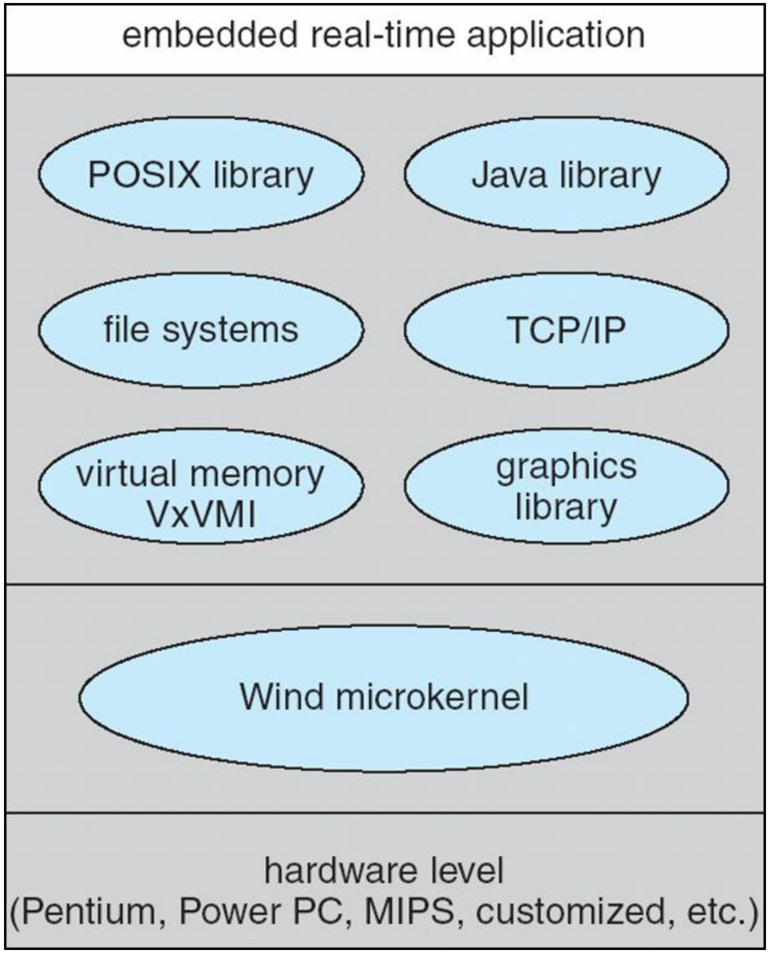
- The Pthread API provides functions for managing real-time threads

- Pthreads defines two scheduling classes for real-time threads:

  (1) SCHED_FIFO - threads are scheduled using a FCFS strategy with a FIFO queue. There is no time-slicing for threads of equal priority

  (2) SCHED_RR - similar to SCHED_FIFO except time-slicing occurs for threads of equal priority

VxWorks 5.0


embedded real-time application
POSIX library
Java library
file systems
TCP/IP
virtual memory VxVMI
graphics library
Wind microkernel
hardware level
(Pentium, Power PC, MIPS, customized, etc.)

Wind Microkernel

- The Wind microkernel provides support for the following:

  (1) Processes and threads

  (2) preemptive and non-preemptive round-robin scheduling

  (3) manages interrupts (with bounded interrupt and dispatch latency times)

  (4) shared memory and message passing interprocess communication facilities

Thanks