Operating System Design

Dr. Jerry Shiao, Silicon Valley University

Real-Time Systems

- Overview
- Characteristics of Real-Time Systems
  - Differ from General-Purpose Systems:
    - General Purpose systems less restrictive, deadline NOT mandatory.
    - User-oriented applications (Spreadsheet, Word Processor, Browser) do NOT require rigid response time.
    - Batch-processing systems has no timing requirements.
- Features of Real-Time Systems
  - Must produce results within certain time limits.
  - Embedded Systems: Computing device that is not obvious to the user (i.e. Household applicances, Automobile systems).
- Implementing Real-Time Operating System
  - Timing Requirements of Real-Time System.
- Real-Time CPU Scheduling
  - Scheduling for Hard Real-Time and Soft Real-Time.
- An Example: VxWorks 5.x

Real-Time Systems

- Overview (Cont)
- What is Multimedia?
  - Difference in how conventional data (text files, programs, binaries) are handled and continuous-media data.
  - Continuous-media data must be delivered (streamed) according to time restrictions (30 Frames per Second).
- Compression
  - The algorithms used to compress multimedia data.
- Requirements of Multimedia Kernels
  - Design of Operating System different for a multimedia systems.
- CPU Scheduling
- Disk Scheduling
- Network Management
- An Example: Cineblitz

Real-Time Systems

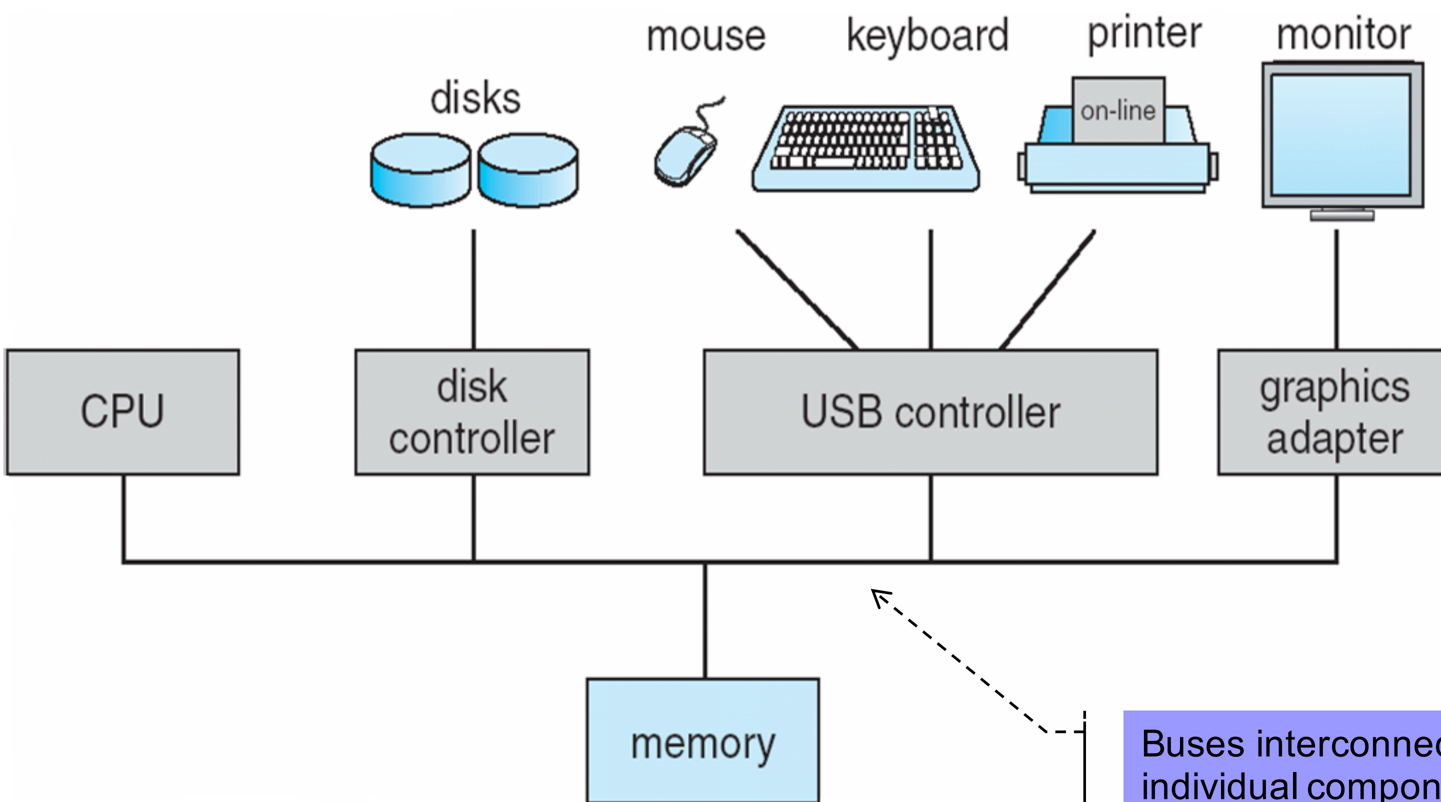
- What are Real-Time Systems?
  - Computer System that requires not only that the computing results are "correct", but results produced within specified deadline (i.e. the result is always deterministic).
- Embedded in Specialized Devices:
  - Microware Ovens, Dishwashers, Thermostats, Cameras, Cell Phones, Automobile Control Systems, Airplane Control Systems, Networking Devices (Switches, Routers).
- Safety-Critical Systems: Missed deadline "catastrophic".
  - Weapons Systems, Antilock Brake Systems, Flight Control Systems, Health Monitoring Systems (Pacemakers).
- Hard Real-Time Systems: Guaranteed critical Real-Time Tasks MUST be completed within deadlines.
- Soft Real-Time Systems: Critical Real-Time Tasks will receive priority over other tasks.

Real-Time Systems

- System Characteristics
- Single purpose
  - Serves single purpose: Control Antilock Brakes, Airplane Nav System.
- Small size
  - Physical size is a constraint: Cell Phone, Wristwatch, Microwave Oven.
  - Small Footpring: Lack CPU processing, memory, disk-less.
- Inexpensively mass-produced
  - Microprocessors inexpensive.
  - Reduce cost with System-On-Chip (SOC).
    - CPU, Memory, MMU, peripheral ports (USB) contained in IC.
- Specific timing requirements
  - Support timing requirements or Real-Time Tasks.
  - Scheduling Algorithms gives highest scheduling priorities.
  - Minimize response time to Interrupt Events.

Real-Time Systems

- System Characteristics
- Bus-Oriented Organization

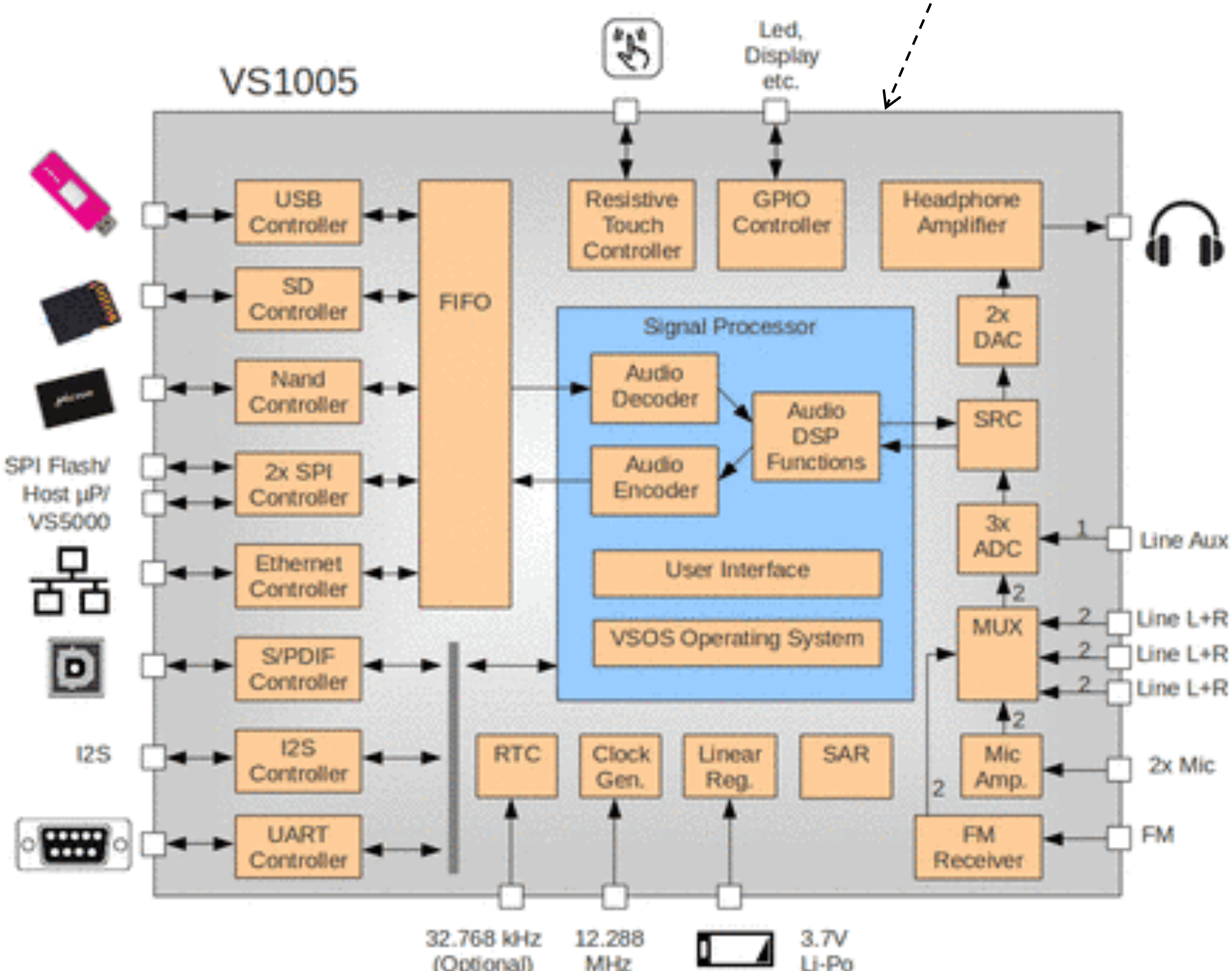


Buses interconnect individual components.

Real-Time Systems

- System Characteristics
- System-On-Chip

CPU, memory (including cache), MMU, peripheral ports, USB ports contained in single Integrated Circuit.



Real-Time Systems

or embedded system

Qn: hard Real-time scheduling? life threatening

Ans: Antilock Brake System, (if it does not work it kills you)

- Features of Real-Time Kernels
- Most real-time systems do not provide the features found in a standard desktop system.
  - Peripheral Devices: Displays, CD Drives, DVD Drives.
  - Windows XP 40+ Million Lines of Source Code.
  - Linux 15+ Million Lines of Source Code. Protection & security, Multiple users.
- Reasons include:
  - Real-time systems are typically single-purpose.
  - Real-time systems often do not interface with a user.
  - Features found in a desktop PC require fast processors and large memory, more substantial hardware than available in a Real-Time system.
  - Cost important factor for Real-Time System.

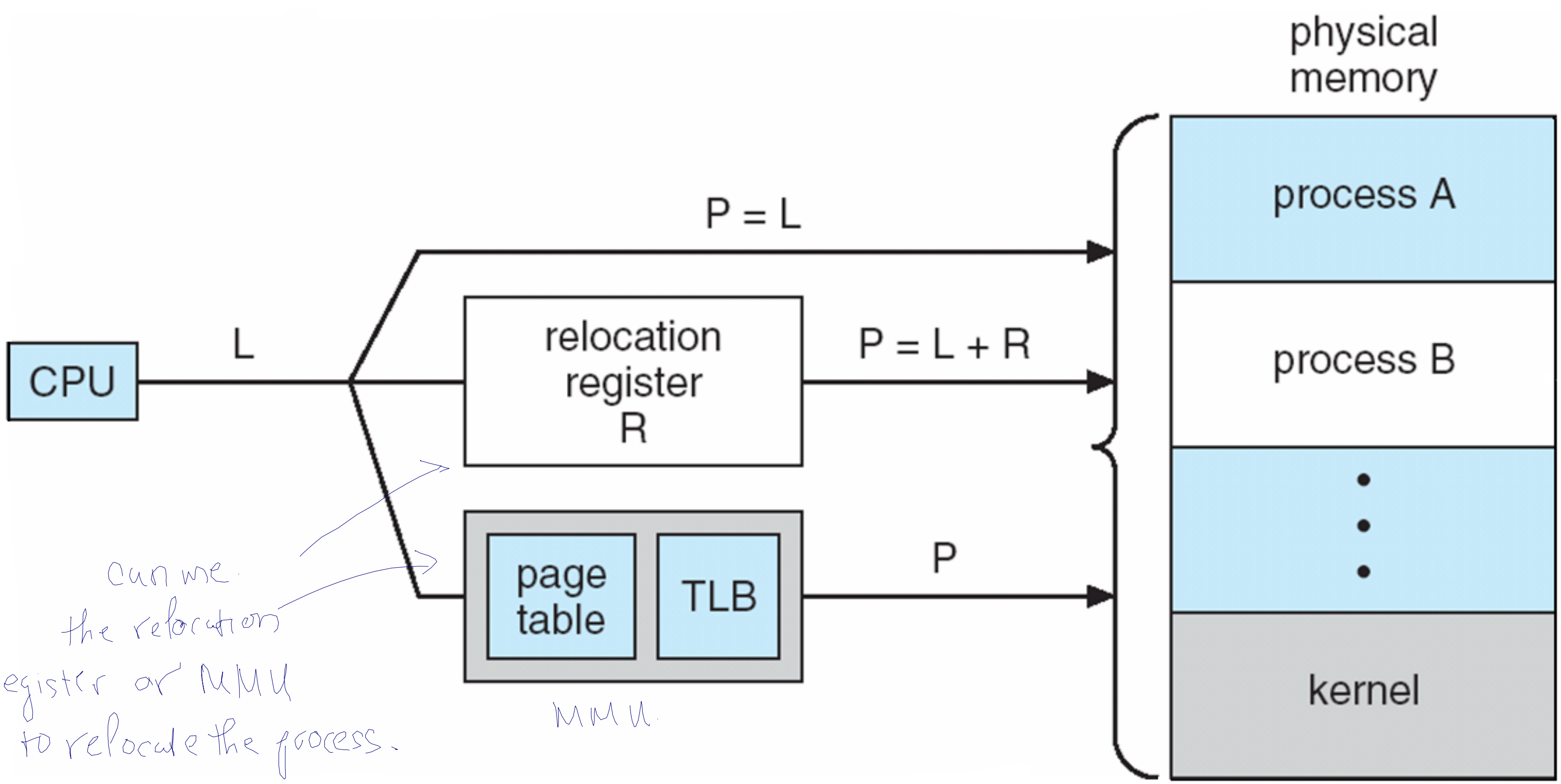
Real-Time Systems

always use relocatable mem, so needs a loader

- Features of Real-Time Kernels
- Address Translation used in Real-Time Systems
  - MMU for Virtual Memory:
    - Increases cost and power consumption.
    - Translation time, Logical to Physical Address (TLB miss) prohibitive.
    - Memory protection between processes.
    - NVRAM (Flash Memory) provides Demand Paging and Swapping.
  - Real-Addressing Mode: Logical Address = Physical Address.
    - No memory protection between processes.
    - Physical location where programs are loaded pre-defined.
    - MMU disabled. ← can be turned off
    - Common in Real-Time System with Hard Real-Time constraints.
  - where to jump to
  - Relocation Register set to memory location of process.
    - MMU set to Physical = Logical + Relocation Register.
    - No memory protection between processes.

Real-Time Systems

- Features of Real-Time Kernels
- Address Translation used in Real-Time Systems



can use the relocation register or MMU to relocate the process.

MMU.

Real-Time Systems

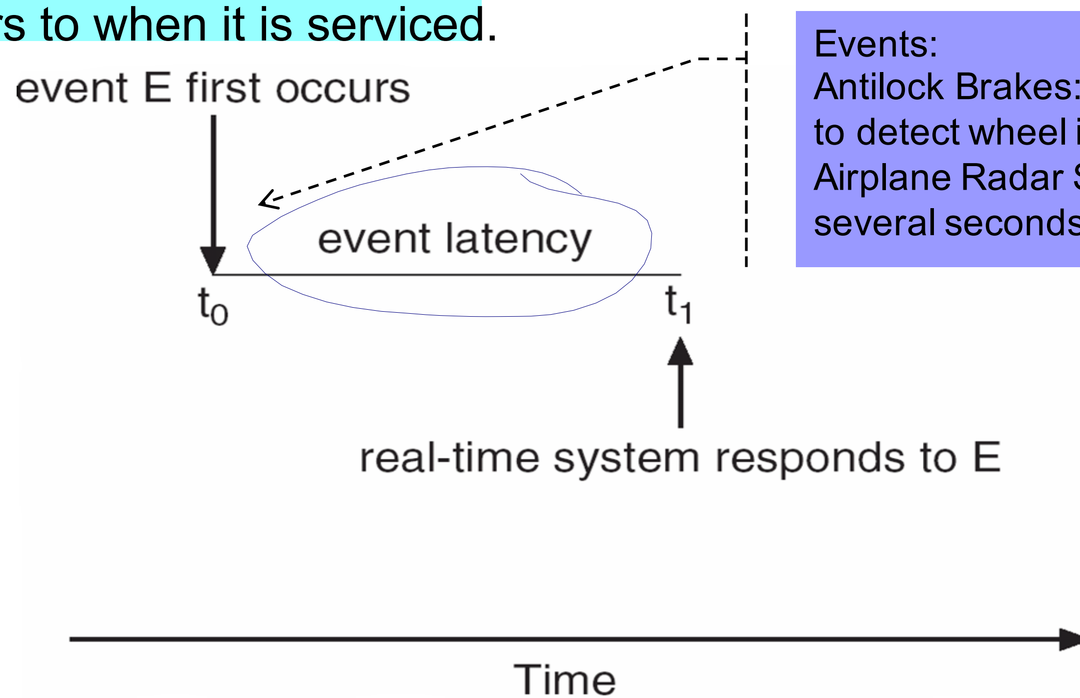
Qn: Why Virtual Mem is not good for hard Real time system?

Ans: Translation Time

- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Preemptive, Priority-Based Scheduling. a must
    - Operating System must respond to Real-Time process as soon as the process requires CPU: Operating System MUST be preemptive and Real-Time Process assigned highest scheduling priority.
    - Preemptive Soft Real-Time Systems: Solaris, Windows XP, Linux, guaranteed assign highest scheduling priority.
    - Preemptive Hard Real-Time Systems: Guaranteed serviced within deadline requirements.
  - Preemptive Kernels: Preemption of task running in Kernel Mode.
    - NOTE: Nonpreemptive Kernel allows Kernel Mode task to run until it exits, blocks or voluntarily yields control of the CPU: Commercial Desktop Operating System (Windows XP) nonpreemptive.
    - Preemption points in long-duration System Calls: Placed in “safe” locations in Kernel (Kernel data structure not being modified).
    - Synchronization of Priority: Priority Inversion.

Real-Time Systems

- Implementing Real-Time Operating Systems
- Real-Time Operating System Event Driven
  - Waiting for event: Either software (timer expires) or hardware (sensor detects condition requiring immediate action).
- Real-Time Operating Systems must provide:
  - Latency must be minimized. very important for hard Realtime system.
    - Event Latency: Amount of time that elapses from when an event occurs to when it is serviced.



Events:
Antilock Brakes: 3-5 MilliSecond to detect wheel is sliding.
Airplane Radar System: Period of several seconds.

Real-Time Systems

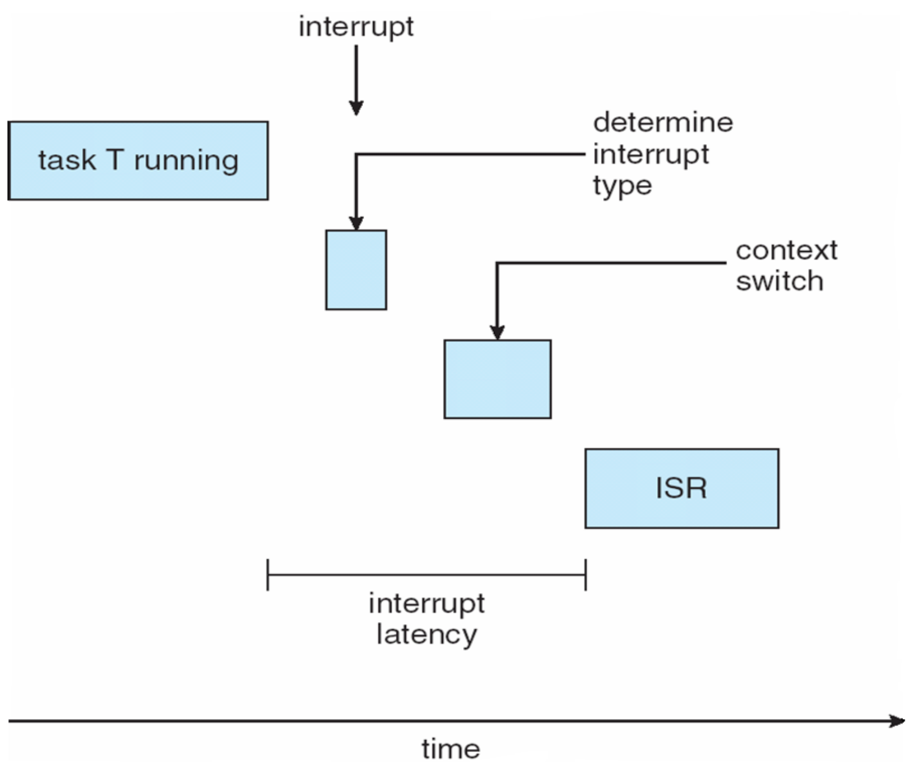
- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Latency must be minimized (Cont)
  - Two types of latencies affecting Real-Time System performance.
    - **Interrupt Latency**

      interrupt flagged. push to stack.

      - Period of time from the arrival of an interrupt at the CPU, save state of the current process, to start of the Interrupt Service Routine (ISR) that services the interrupt. has index to the interrupt table
        - Between arrival of an interrupt and the start of the Interrupt Service Routine: Dispatch Latency.
      - Real-Time Operating Systems MUST minimize Interrupt Latency to ensure Real-Time Task receives attention. no other interrupt should take over priority BUT
      - Amount of time interrupts are disabled while Kernel data structures are being updated, MUST be short.
      - Hard Real Time Systems: Interrupt Latency MUST be bounded to guarantee deterministic behavior.

Real-Time Systems

- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Latency must be minimized (Cont)
  - Two types of latencies affecting Real-Time System performance.
    - **Interrupt Latency**



Real-Time Systems

- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Latency must be minimized (Cont)
  - Two types of latencies affecting Real-Time System performance.
    - **<u>Dispatch Latency</u>:** Amount of time required for the Scheduling Dispatcher to stop one process and start another .

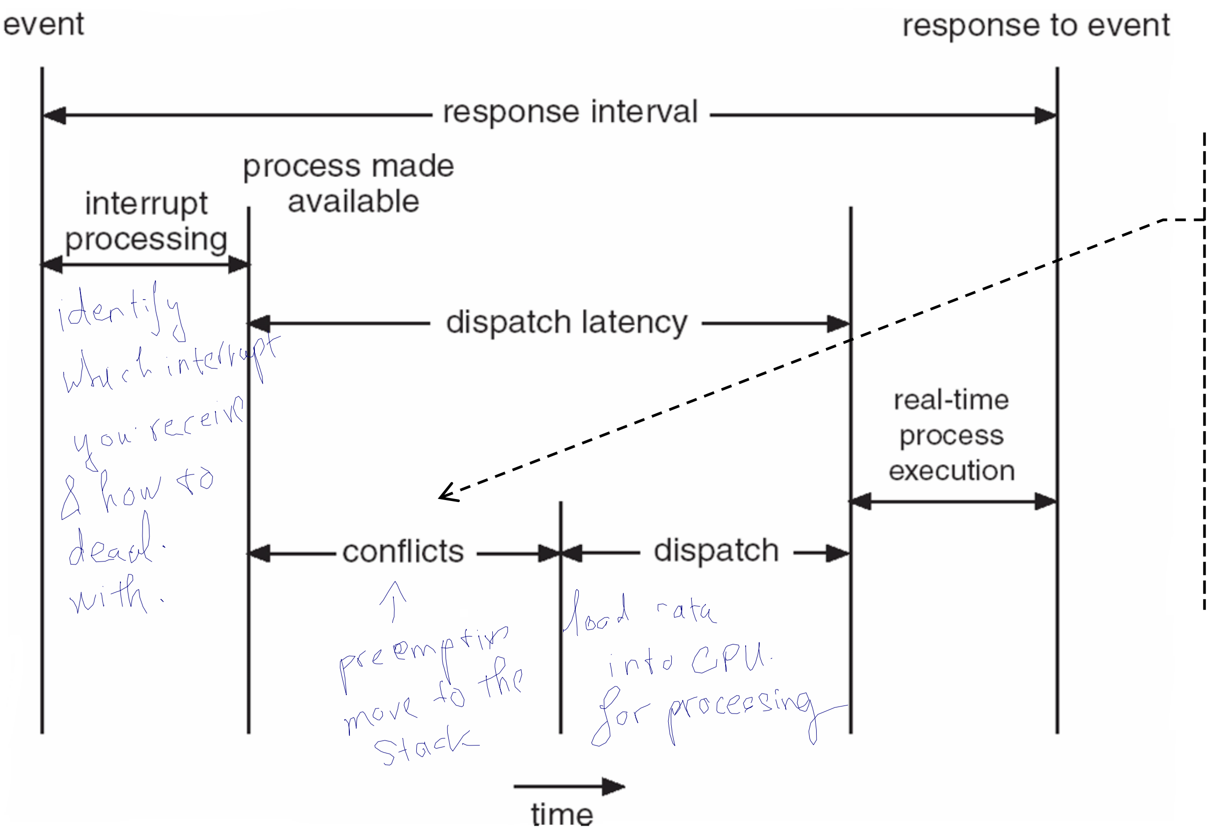
      -time to put current process to sleep

      - Minimized by Real-Time Operating System: Preemptive Kernel help keep Dispatch Latency low.
    - <u>Conflict Phase</u> of Dispatch Latency:
      - Preemption of any process running in the Kernel.
      - Release by low-priority processes of resources needed

Real-Time Systems

Qn. Real time System: Which is not related to Interrupt Latency?
Ans use the scheduler to schedule the highest priority ISR. (dispatch latency)

- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Latency must be minimized (Cont)

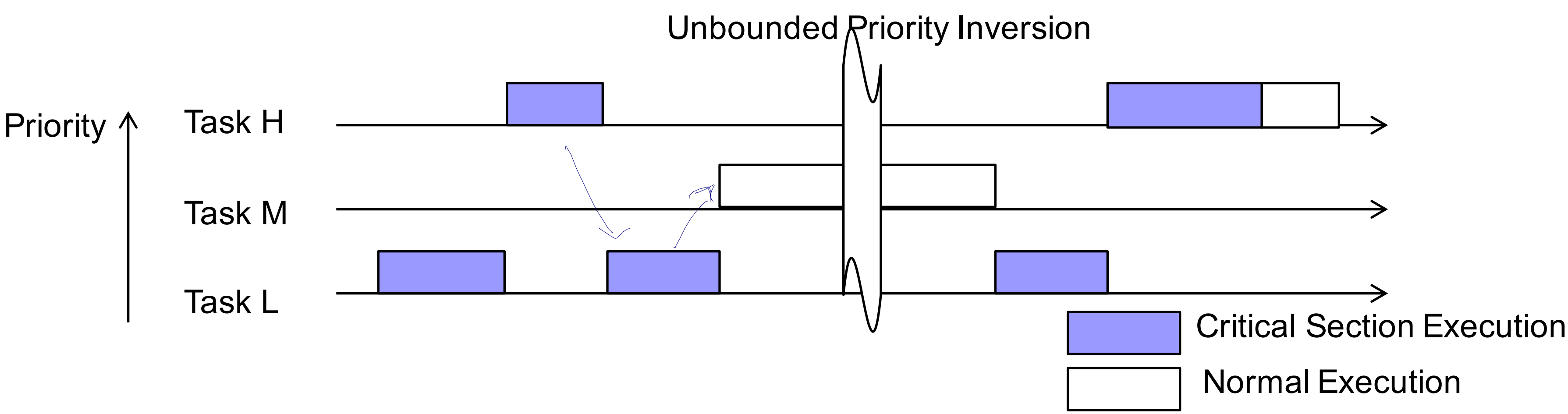


Dispatch Latency:
In Conflict Phase are two components:
1) Preemption of any process running in the Kernel.
2) Release low-priority processes of resources needed by high-priority process.

Real-Time Systems

- Implementing Real-Time Operating Systems
- Real-Time Operating Systems must provide:
  - Latency must be minimized (Cont)
  - Priority Inversion: Resolve Dispatch Latency issue caused by high-priority process waiting for Kernel data currently owned by lower-priority processes.

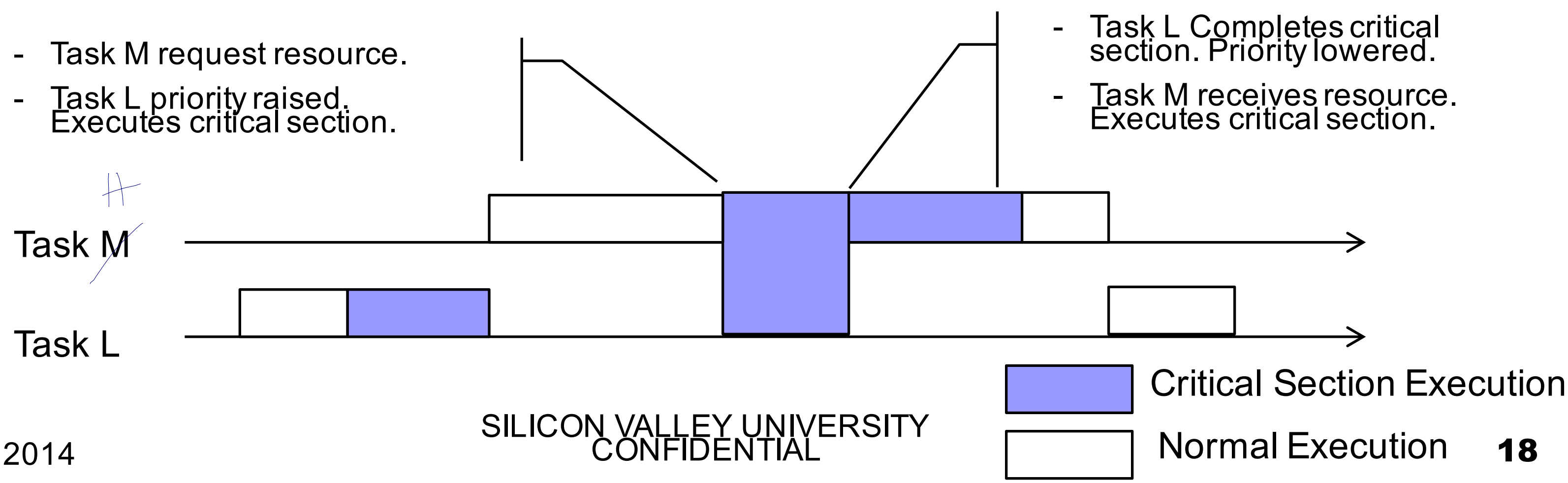
has to deal with Priority.



Real-Time Systems

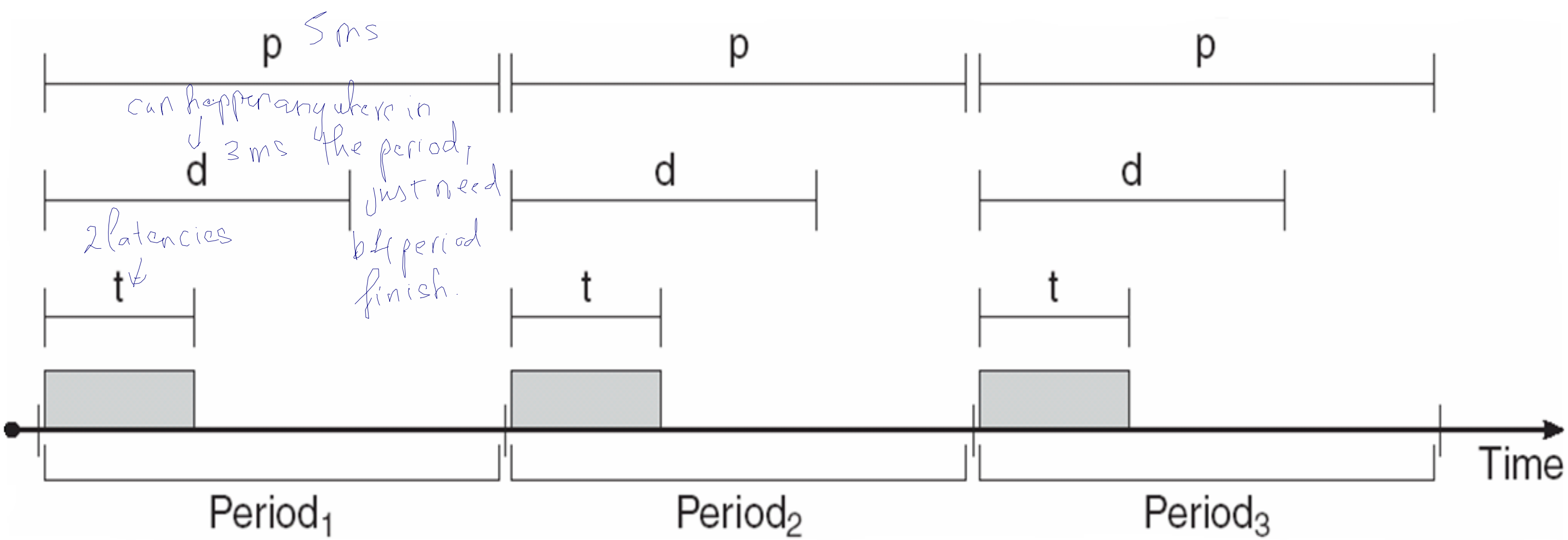
Q: not assoc with Dispatch Latency?
Ans: Select the Interrupt Services Routine
this is Interrupt Latency.

- Priority Inheritance:
  - Low-priority task has priority raised until completes critical section (releases shared resource).
  - Nested resource locks can lead to deadlock.
    - Avoid deadlock by allowing each task to own one shared resource.
    - Do not allow nested locks.
    - Overhead raising priority and then lowering priority.



Real-Time Systems

- Real-Time CPU Scheduling
- Scheduling for Hard Real-Time Systems.
  - **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 fixed processing time once CPU is acquired.
  - Priority can be assigned based on deadline or rate requirements.

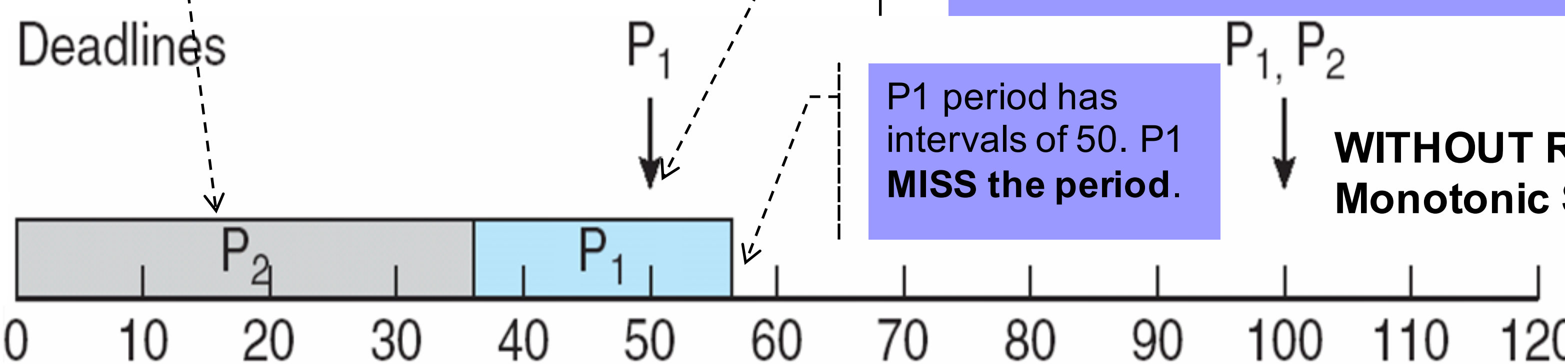


Real-Time Systems

- Real-Time CPU Scheduling
- Admission Control will use deadline requirements to admit or reject a process, on guarantee that the process will complete on-time.
- Rate-Monotonic Scheduling Admission Control fixed Priority.
  - Periodic Tasks using **Static Priority Policy with Preemption**.
  - Priority inversely based on its period: Shorter the period, higher priority.
  - Assign higher priority ~~to~~ task that uses CPU quickly (short period).
  - Processing time of periodic period is same for each CPU Burst.

P1 = 50 P2 = 100
T1 = 20 T2 = 35
1) P2 higher priority than P1.

2) P2 executes and completes at T2 (35).
3) P1 executes at 35.
4) P1 completed at 55.



P1 period has intervals of 50. P1 **MISS the period**.

WITHOUT Rate-Monotonic Scheduling.

Real-Time Systems

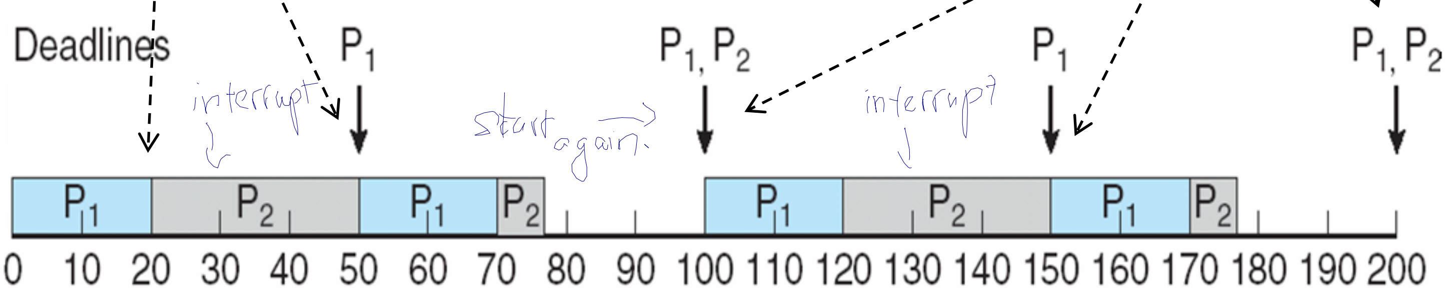
- Real-Time CPU Scheduling
- Rate-Monotonic Scheduling
  - CPU Utilization: T1/P1 (20/50=.40) + T2/P2 (35/100=.35) = .75 (75%)

base on deadline, P1 priority > P2

P1 = 50 P2 = 100
T1 = 20 T2 = 35
Shorter Periods = Higher Prioiity.
1) P1 higher priority than P2. Completes T1 (20) within Period.
2) P2 starts T2 (35), but interrupted at 50 by P1.
3) P1 runs until time 70, and P2 completes at 75.

With Rate-Monotonic Scheduling.

P1 Period has intervals of 50. P1 **completes within Period.**
P2 Period has intervals of 100. P2 completes within Period.



should be high.

Qn: which statement is FALSE with Rate Monotonic?
Ans: the lower the rate, the lower priority

Real-Time Systems

- **Real-Time CPU Scheduling**
- Rate-Monotonic Scheduling
- Limitation: CPU Utilization is Bounded.
  - Two processes, Bound = 83%. Bound is 69% when processes approach infinity,
  - CPU Utilization = T1/P1 (25/50=.50) +T2/P2 (35/80=.44) = .94 (94%)

If CPU is more than Bound, can not we use Rate Monotonic technic.

can meet the deadline.

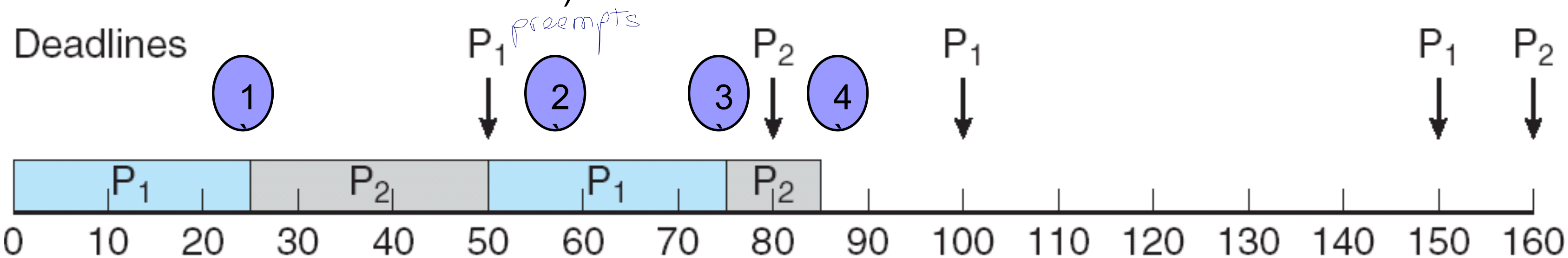
deadline time to process

does not say whether the process meets the deadline.

With Rate-Monotonic Scheduling.

P1 = 50 P2 = 80
T1 = 25 T2 = 35

1) T1 CPU Burst completes at 25.
2) T2 CPU Burst (25) preempted at 50 by P1. T2 has 10 left.
3) T1 CPU Burst completes at 25.
4) T2 CPU Burst (10) completes at 85.
5) **P2 MISSED Period at 80**.



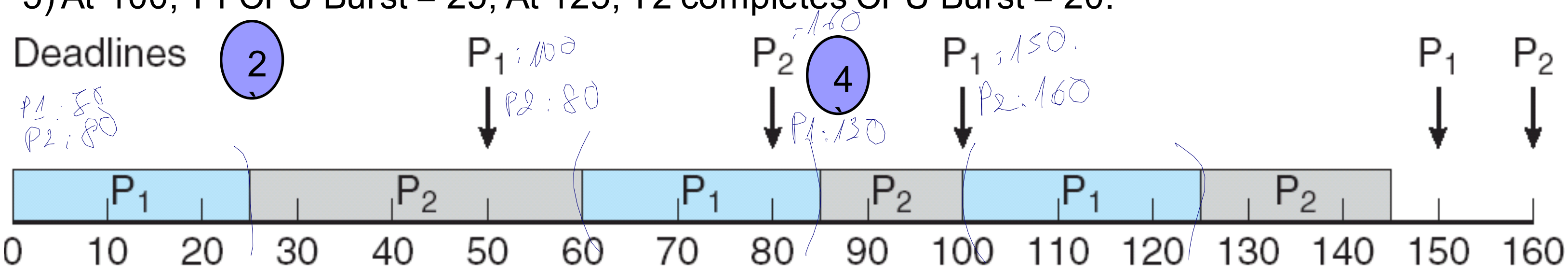
Real-Time Systems

- ## Real-Time CPU Scheduling
- Earliest-Deadline-First Scheduling Admission Control
- Priorities are assigned according to deadlines: Earlier the deadline, the higher the priority, later the deadline, the lower the priority.
- Process ready to be scheduled:
  - Deadline requirements announced to the system.
  - **Priorities adjusted** to reflect Deadline of schedulable process.

P1 = 50 P2 = 80

T1 = 25 T2 = 35

1) At 0, P1 is the earliest deadline, CPU Burst T1 = 25.
2) At 25, T2 CPU Burst = 35. P2 (Deadline = 80) has higher priority than P1 (Deadline = 100)
3) At 60, T1 CPU Burst = 25.
4) At 85, T2 CPU Burst = 15, preempted by P1 (Deadline=150) over P2 (Deadline=160)
5) At 100, T1 CPU Burst = 25, At 125, T2 completes CPU Burst = 20.



Real-Time Systems

- Real-Time CPU Scheduling
- Proportional Share Scheduling
- Total CPU time, ***T*** shares, are allocated among all processes in the system.

  if deadline short → more shares (tickets)
  large → less

- An application receives ***N*** shares where ***N < T.***
- This ensures each application will receive ***N / T*** of the total processor time.
- Works in conjunction with Admission Control Policy: Only admit a Client requesting equal or less than number of shares that are available.
  - Process does not get scheduled, if Admission Control denies entry.

70% of the time the tickets go to the shorter Deadline (base on Stats).

Real-Time Systems

Qn: Which one is NOT the param for Realtime scheduling?
Ans: Shed_normal ← not used.

- Real-Time CPU Scheduling
- Pthread Scheduling
- The Pthread API provides functions for managing Real-Time threads.

reason is realtime system likes to hold on to the CPU to process the event until complete, e.g. ABS system

- Pthreads defines two scheduling classes for Real-Tme Threads:
  - SCHED_FIFO - Threads are scheduled using a FCFS strategy with a FIFO queue. There is no time-slicing for threads of equal priority.
  - SCHED_RR - Similar to SCHED_FIFO except time-slicing occurs for threads of equal priority.

most realtime uses FIFO

will interrupt the process for slicing → best for multimedia system.

- Pthread API:
  - pthread attr getsched policy(pthread attr t *attr, int *policy)
  - pthread attr setsched policy(pthread attr t *attr, int *policy)
  - Param attr: Pointer to set of attributes for the thread.
  - Param policy: Pointer to integer value SCHED_FIFO, SCHED_RR, SCHED_OTHER.

Real-Time Systems

- Real-Time CPU Scheduling
- VxWorks 5.x ← embedded system that is commercial available, stable
- Supports Hard Real-Time Operating System.
- WindRiver Systems: VxWorks and Windriver Linux.
  - Acquired by Intel Corporation.
  - Automobiles, Consumer and Industrial Devices, Networking Equipment (Switches and Routers), Space Equipment (Mars terrain rovers).
- VxWorks centered on the Wind microkernel.
  - Supports processes and threads using Pthread API.
  - Supports two scheduling models: Preemptive Scheduing and Nonpreemptive Round-Robin scheduling with 256 priority levels.
  - Hard Real-Time supports bounded interrupt and dispatch latency times for interrupts.
  - Interprocess Communication using shared memory and message passing. Tasks can communicate using Pipes (FIFO queue).
  - Supports semaphores and mutex locks with Priority Inheritence .

Real-Time Systems

- Real-Time CPU Scheduling
- VxWorks 5.x (Cont)
- Component Libraries: POSIX, Java, TCP/IP Networking.
- All components optional, Embedded System can be customized to the customer requirements.
- Two levels of Virtual Memory:
  - Allows control of the cache on a per-page basis: Cache-coherency Policy used to ensure caches of shared data are not different.
  - Virtual Memory component (VxVMI) and MMU: Allows task to mark data areas as "private". Kernel code pages and Interrupt Vector can be marked as "Read-Only".

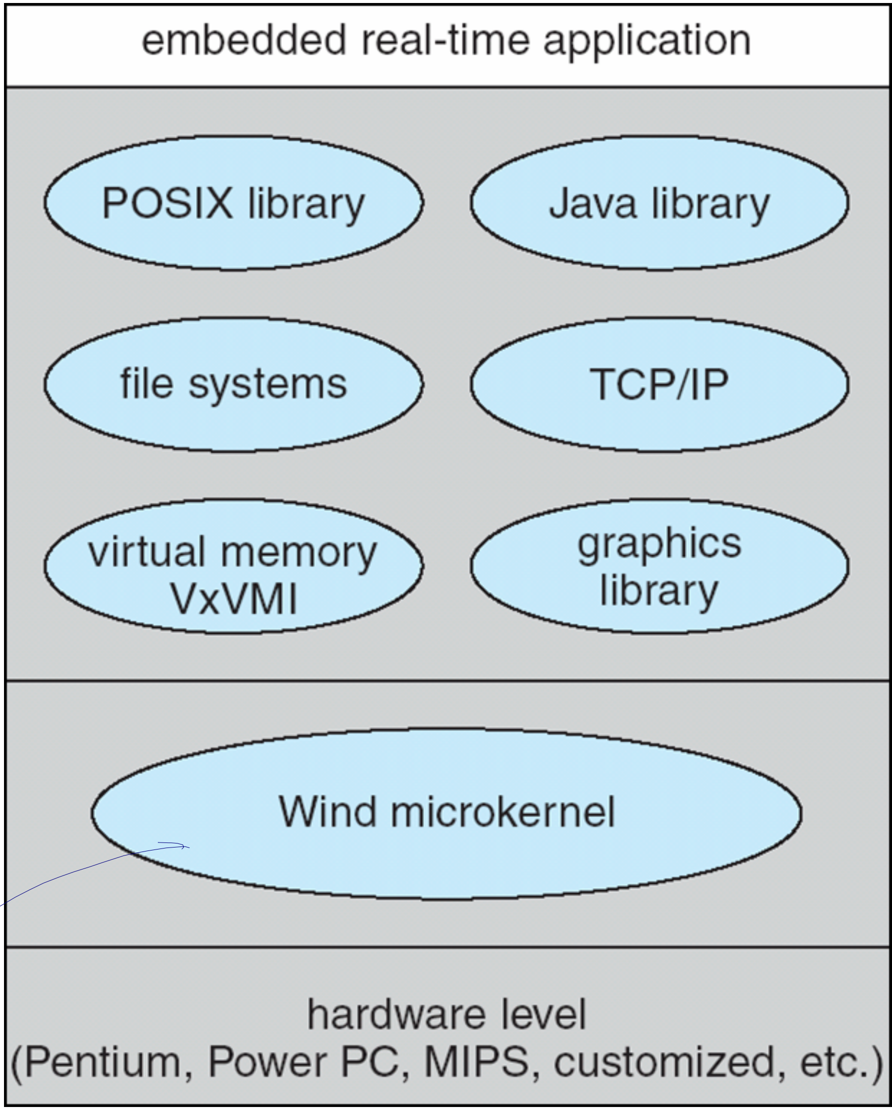
Linux differentiates User / Kernel.

- VxWorks 5 does not distinguish between User and Kernel mode: Applications run in Kernel mode and is able to address all address space.
  - VxVMI used to prevent user applications from writing Kernel space.
- VxWorks 6 supports Kernel Mode and User Mode: VxWorks Real-Time Processes run in User Mode and Kernel runs in Kernel Mode.

Real-Time Systems

- Real-Time CPU Scheduling
- VxWorks 5.x (Cont)
- Wind microKernel has bare minimum of features.
- Add more features (networking, file systems, memory management etc. specialized libraries are included.
- By this approach the system will only have the features that are actually needed and the footprint will be as small as possible.

events are handled in kernel.



Real-Time Systems

- Summary
- Real-Time System require results to arrive within deadline period.
- Embedded specialized (single function) Real-Time Systems in consumer and industrial devices.
- Soft Real-Time Systems (higher priority than user processes) and Hard Real-Time Systems (guaranteed deadline periods).
- Scheduler supporting Real-Time Systems:
  - Priority-based algorithm with preemption.
  - Kernel can be preempted.
- Minimize Interrupt and Dispatch Latency.
- Real-Time Scheduling Algorithms:
  - Rate-monotonic scheduling assigns higher priority to processes requiring the CPU more often.
  - Earliest-Deadline-First scheduling assigns priority using deadlines.
  - Proportional Share Scheduling divides up processor time into shares.
  - Pthread API provides library intreface to schedule Real-Time threads.

Multimedia Systems

- Operating System Data: Text Files, Programs, Binaries, Word-Processing Documents, Spreadsheets.
- What is Multimedia?
  - Continuous-media (audio and video) data.
- Multimedia data includes
  - MP3 Audio, MPEG Streaming Video, and Video Clips
  - Live Webcasts of Speeches or Sporting Events
  - Multimedia applications includes separate audio and video tracks.
- Multimedia data may be delivered to:
  - Desktop PC's.
  - Small Devices: Handheld devices (PDAs, smart phones).
- Common standards used for representing multimedia video and audio files.

Multimedia Systems

- Media Delivery
- Multimedia data is stored in the file system like other ordinary data.
- However, multimedia data must be accessed with specific timing requirements.
- For example, video must be displayed at 24-30 **frames** per second. Multimedia video data must be delivered at a rate which guarantees 24-30 frames/second.
- Video file must be accessed from the File System at a rate consistent with the rate at which the video is being displayed.
  - **Continuous-media data** is data with specific rate requirements.

Multimedia Systems

- Media Delivery
- Local Playback: Data delivered from local File System.
  - DVD on laptop. MP3 Audio File on handheld MP3 Player.
- **Streaming** is delivering a multimedia file from a server to a client - the deliver occurs over a network connection.
  - Personnel computer, PDA, Cell Phone.
- There are two different types of streaming:
  - **Progressive download** - The client begins playback of the multimedia file as it is delivered (HTTP Web Server). The file is stored on the client computer (YouTube, ESPN and CNN).
  - **Real-time streaming** - The multimedia file is delivered by Streaming Server to, but not stored on, the client's computer.
  - Real-time Streaming preferable: Media files too large to store, more secure, long videos, Internet Radio, TV Broadcasts.

Multimedia Systems

- Media Delivery
- Random Access Feature: Progressive Download or Real-Time Streaming.
  - Ability to move around within the Media Stream (position within the file).
- Real-Time Streaming:
  - Live Streaming: Deliver an event, concert or lecture, live as it is actually occurring.
    - Radio program broadcast, Live webcams, Video Conferencing.
    - Live Delivery does NOT allow Random Access Feature (no late viewing of earlier points in the media stream).
  - On-Demand Streaming: Does not take place as the event is occurring.
    - Full-length movies and archive lectures.
    - No notion of arriving late.
    - Client may or may not have Random Access to the stream.
  - Streaming Media Products: RealPlayer, Apple QuickTime, Windows Media Player.

Multimedia Systems

- Characteristics of Multimedia Systems
- Multimedia files can be quite large.
  - 100 Minutes MPEG-1 Video File = 1.125 GBytes of storage.
  - 100 Minutes HDTV = 15 GBytes of storage.
  - Streaming Server with Digital Video Library require several TeraBytes of storage.
- Continuous media data may require very high data rates.
  - Digital frame of color video at resolution of 800 X 600 Pixels. Using 24 bits to represent color of each pixel, single frame needs 800 X 600 X 24 = 11.520 Mbits of data. Frames displayed at 30 frames per second: Bandwidth in excess of 345 Mbps is required.
- Multimedia applications may be sensitive to timing delays during playback of the media.
  - Start delivery of continuous-media file during playback, delivery must continue at the rate, otherwise the video will be subject to pauses or stalls.

Multimedia Systems

- Operating System Issues
- Deliver of Continuous-media data, Operating System must guarantee specific rate and timing requirements.
- Quality of Service (QOS) Requirements:
  - Influences CPU Scheduling, Disk Scheduling, and Network Management.
  - Compression and Decoding require CPU processing.
  - Multimedia task must be scheduled with enough priorities to ensure deadline requirements of continuous-media data are meet.
  - File system must meet the rate requirements of continuous-media data.
  - Network Protocols must support bandwidth requirements: Minimize Delay and Jitter.

Multimedia Systems

- Compression
- The size and rate requirements of multimedia systems, require compressing multimedia files into a smaller form.
  - Useful for streaming across Network.
  - Compression Ratio: Ratio of orig file size to compressed file.
- Files compressed (Encoded) as lossy or lossless:
  - Lossy: Some of the original data are lost when file is decoded.
    - Images (pictures), audio, and video can tolerate “lost” data.
    - Eliminate very high or low frequencies undetectable by human ear.
    - **Video lossy compression stores ONLY differences between frames**.
  - Lossless: Ensures the compressed file can be restored (Decoded) to its original form.
    - Text file, computer programs (Zipped files).

Multimedia Systems

- Compression
- Lossy Compression Schemes: MPEG Compression (Moving Picture Experts Group) for continuous-media:
  - MPEG is a set of file formats and compression standards for Digital Video.
    - Layers 3 and 2 apply to audio and video portion of media file.
    - Layer 1 (Systems Layer) has timing information for MPEG player to multiplex and synchronize audio and video during playback.
  - MPEG-1: Digital video and audio stream. Resolution is 352 X 240 @ 30 frames/second. Rate of 1.5Mbps.
    - Quality of VCR videos.
    - MP3 Audio is MPEG-1 Layer 3 (audio portion).
    - Compression Ratio of 200:1.
    - Download short video clips over Internet.

Multimedia Systems

- Compression
- Lossy Compression Schemes: MPEG Compression (Moving Picture Experts Group) for continuous-media:
  - MPEG-2: Used for compressing DVD and high-definition television (HDTV).
    - Levels and Profiles of video compression.
    - Level: Resolution of the video.
    - Profile: Characterize video quality.
    - Higher Level/Profile, higher required data rate (1.5 Mbps to 15 Mbps).
    - High data rate makes MPEG-2 more suitable for local playback.
  - MPEG-3: Discontinued, and never released. Sometime confused with MP3 (MPEG-1 Audio Layer 3).

Multimedia Systems

- Compression
- Lossy Compression Schemes: MPEG Compression (Moving Picture Experts Group) for continuous-media:
  - MPEG-4 - Used to transmit audio, video, and graphics, including 2-D and 3-D animation layers. Allows end users to interact with the file during playback.
    - Virtual tour of home, moving room to room.
    - Scalable level of quality, allowing delivery over slow network connections (56Kbps modems) or high-speed networks.
    - MPEG-4 audio and video delivered over wireless devices (Handheld computers, PDAs, Cell Phones).

Multimedia Systems

- Requirements of Multimedia Kernels
  - Differ from requirements of traditional applications (Word Processor, compilers, spreadsheets).
- The operating system must guarantee the specific data rate and timing requirements of continuous media.
  - Audio and Video data playback demands deliver within certain deadline and continuous fixed rate.
- Periodic Processes: Processes that request data at constant intervals or periods.
  - Frame unable to be displayed at deadline are omitted.
  - At 30 Frames/second = 1/30th = 3.34 hundredths of a second.
- Rate requirements and deadlines are known as **Quality-of-Service** (**QoS**) guarantees.

Multimedia Systems

- Requirements of Multimedia Kernels
- Quality of Service (QOS) Levels:
  - Best-Effort Service: System makes a Best-Effort attempt to satisfy the requirements, NO Guarantees are made.
  - Soft QOS: Treats different types of traffic in different ways, giving certain traffic streams higher priority than other streams. NO Guarantees are made.
  - Hard QOS: Quality-Of-Service requirements are Guaranteed.
- Traditional Operating Systems uses:
  - Best-Effort Service.
  - Over-provisioning: Assume the total amount of resources available is larger than a worst-case workload.
- Multimedia Systems cannot behave as traditional Operating Systems: the system MUST provide continuous-media applications with the guarantees of hard QOS.

Multimedia Systems

- Requirements of Multimedia Kernels
- Parameters Defining QOS for Multimedia Applications:
  - Throughput: Total amount of work during certain interval. Throughput is the required Data Rate.
  - Delay: Elapsed time from when a request is submitted to when the result is produced (Time when a Client requests a media stream to when the stream is delivered).
  - Jitter: Related to Delay (where Delay refers to the time a user must wait to receive a Stream, jitter refers to delays during playback.
    - Unacceptable for continuous-media application.
    - Acceptable for on-demand Real-Time streaming.
    - Jitter compensated by buffering data (5 seconds) before playback.
  - Reliability: How errors are handled during transmission and processing of continuous media.
    - Errors occur due to lost packets or processing delays by CPU.

Multimedia Systems

- Requirements of Multimedia Kernels
- Parameters Defining QOS for Multimedia Applications: (Cont)
  - QOS Negotiation between Client and Server:
    - Client negotiates a data rate (Speed of the Client's connection to the network), agreeing to a certain level of quality.
    - Many Media Players allow Client to configure the Media Player according to the speed of the client's connection to the network.
  - QOS Guarantee provided by using Admission Control:
    - Admitting a request for service ONLY if the server has sufficient resources to satisfy the request.

Multimedia Systems

- Requirements of Multimedia Kernels
- Parameters Defining QOS for Multimedia Applications: (Cont)
  - Admission Control with Semaphores:
    - Semaphores as a method of implementing simple Admission-Control Policy.
    - Initialize Semaphore to the number of resources available.
      - After all resources are in use, wait( ) blocks until signal ( ).
  - Admission Control with Resource Managers:
    - Resource Reservation method:
      - Resource Manager for each type of resource (CPU, Memory, File System, Devices, Network).
      - Request for resource has QOS requirements : Required Data Rate.
      - QOS may be negotiated between Client and Server.

Multimedia Systems

- CPU Scheduling
- Soft Real-Time Systems give scheduling priority to critical processes.
  - No guarantee as to WHEN the critical process scheduled.
- Hard Real-Time Systems require critical process will be serviced within a guaranteed period of time.
  - Multimedia systems require hard Real-Time scheduling to ensure critical tasks will be serviced within timing deadlines.
  - Most hard realtime CPU scheduling algorithms assign Real-Time processes static priorities that do not change over time.
    - Dynamic priority for non-Real-Time processes, with the intent of giving higher priority to interactive processes.

Multimedia Systems

- Disk Scheduling
- Disk scheduling algorithms must be optimized for continuous media.
  - Timing deadlines and Rate requirements.
  - Disks have relatively low transfer rates and relatively high latency rates.
  - Reducing latency rates may result in Scheduling Policy that does NOT prioritize according to deadlines.
- Earliest-Deadline-First (EDF) Scheduling.
  - Queue to order requests according to the time each request must be completed (deadline).
  - Similar to Shortest-Seek-Time-First (SSTF) , instead of servicing request closest to current cylinder, service request with the closest deadline first.
  - <u>EDF could have higher seek times</u>, since movement does not regard current position.

Multimedia Systems

- Disk Scheduling (Cont)
- SCAN-EDF Scheduling.
  - SCAN-EDF scheduling is similar to EDF except that requests with the same or relatively close deadlines are batched together and ordered according to a SCAN policy.
- Batching Requests has many techniques:
  - Only requirement is reordering requests within batch must not prevent request from being serviced within its deadline.
  - Batch Requests according to relatively close deadline.
  - Batch Requests within a threshold (within 100MilliSeconds).

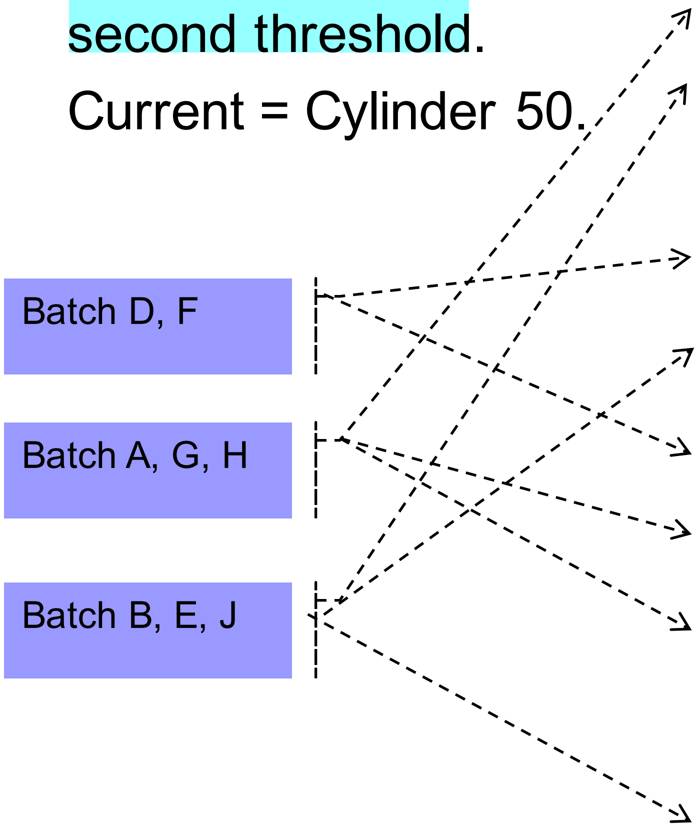
Multimedia Systems

- Disk Scheduling (Cont)
- SCAN-EDF Scheduling
  - Batch within 100 Milli-second threshold.

    Current = Cylinder 50.

?

request	deadline	cylinder
A	150	25
B	201	112
C	399	95
D	94	31
E	295	185
F	78	85
G	165	150
H	125	101
I	300	85
J	210	90



Multimedia Systems

- Network Management
- Preserving rate requirements is foremost QOS issue.
- Techniques for CPU Scheduling and Disk Scheduling algorithms can serve QOS requirements.
- Streaming across Internet can affect QOS Demands.
  - Network encounters congestion, delays, and other network traffic issues beyond control of the originator of the data.
  - Multimedia data, timing requirements must be synchronized between server delivering content and client playing it back.
- RTP (Real-Time Transport Protocol)
  - Internet standard for delivering Real-Time data (audio/video).
  - Provides features that allow a receiver to remove jitter introduced by delays and congestion in the network.

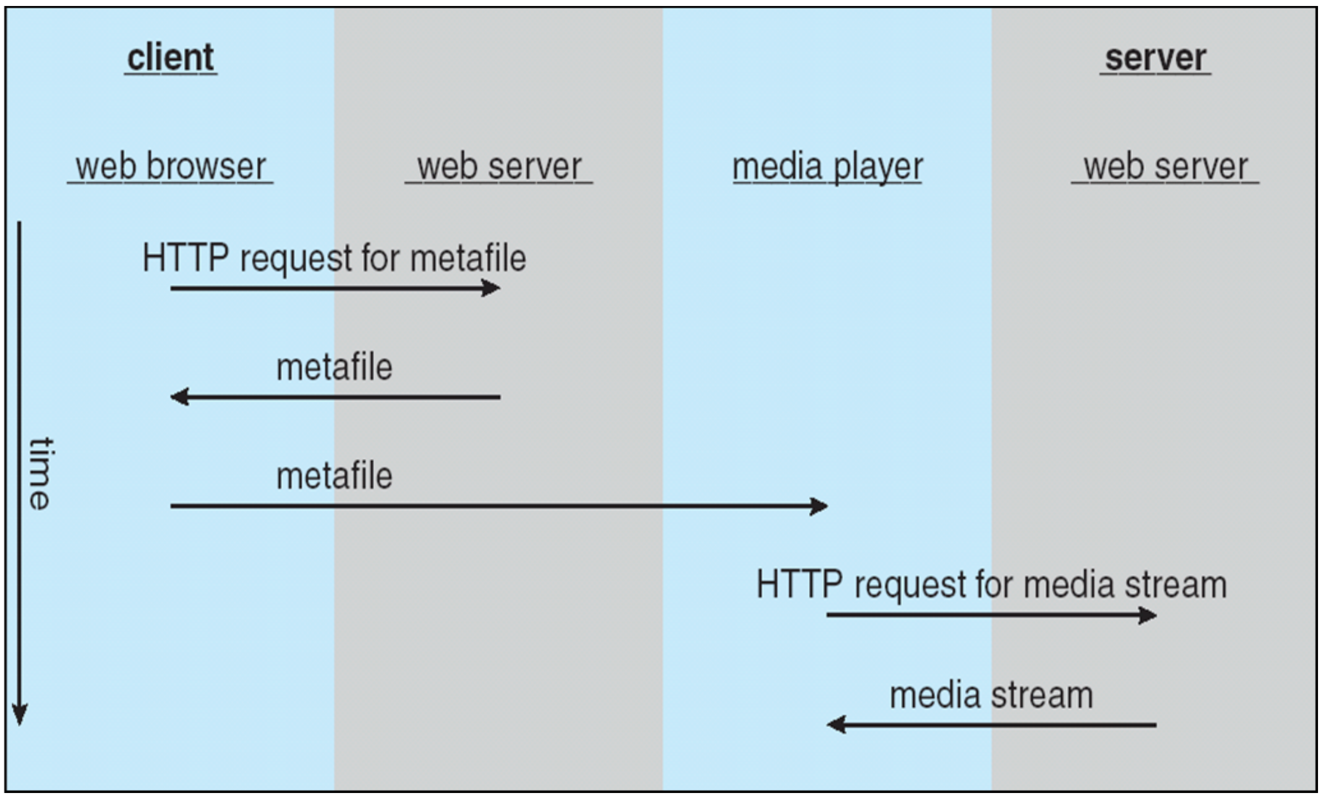
Multimedia Systems

- Network Management
- Three general methods for delivering content from a server to a client across a network:
  - **Unicasting** - The server delivers the content to a single client. Multiple clients requires separate unicast to each client.
    - Most streaming media delivered across unicast channels.
  - **Broadcasting** - The server delivers the content to all clients, regardless whether they want the content or not.
  - **Multicasting** - The server delivers the content to a group of receivers who indicate they wish to receive the content.
    - Clients should be physically close to the server or to intermediate routers supporting multicasting protocol (IGMP).

- Network Management
- Deliver of Streaming Media
- Stream from Web Server using Hypertext Transport Protocol (HTTP)
  - Clients use Media Player (QuickTime, RealPlayer, Windows Media Player) to play back media from Web Server.
  - Client request Metafile:
    - Contains location (URL) of streaming media file.
    - Metafile received by Client Web Browser, starts the Media Player (Real Audio stream needs RealPlayer, streaming Windows media needs Windows Media Player).
    - Media Player contacts Web Server and Web Server delivers streaming media using standard HTTP.
  - HTTP stateless protocol: Web Server does not maintain state (status) of connection and the delivery of streaming media.

Multimedia Systems

- Network Management
- Deliver of Streaming Media (Cont)
  - Streaming Media from conventional Web Server:

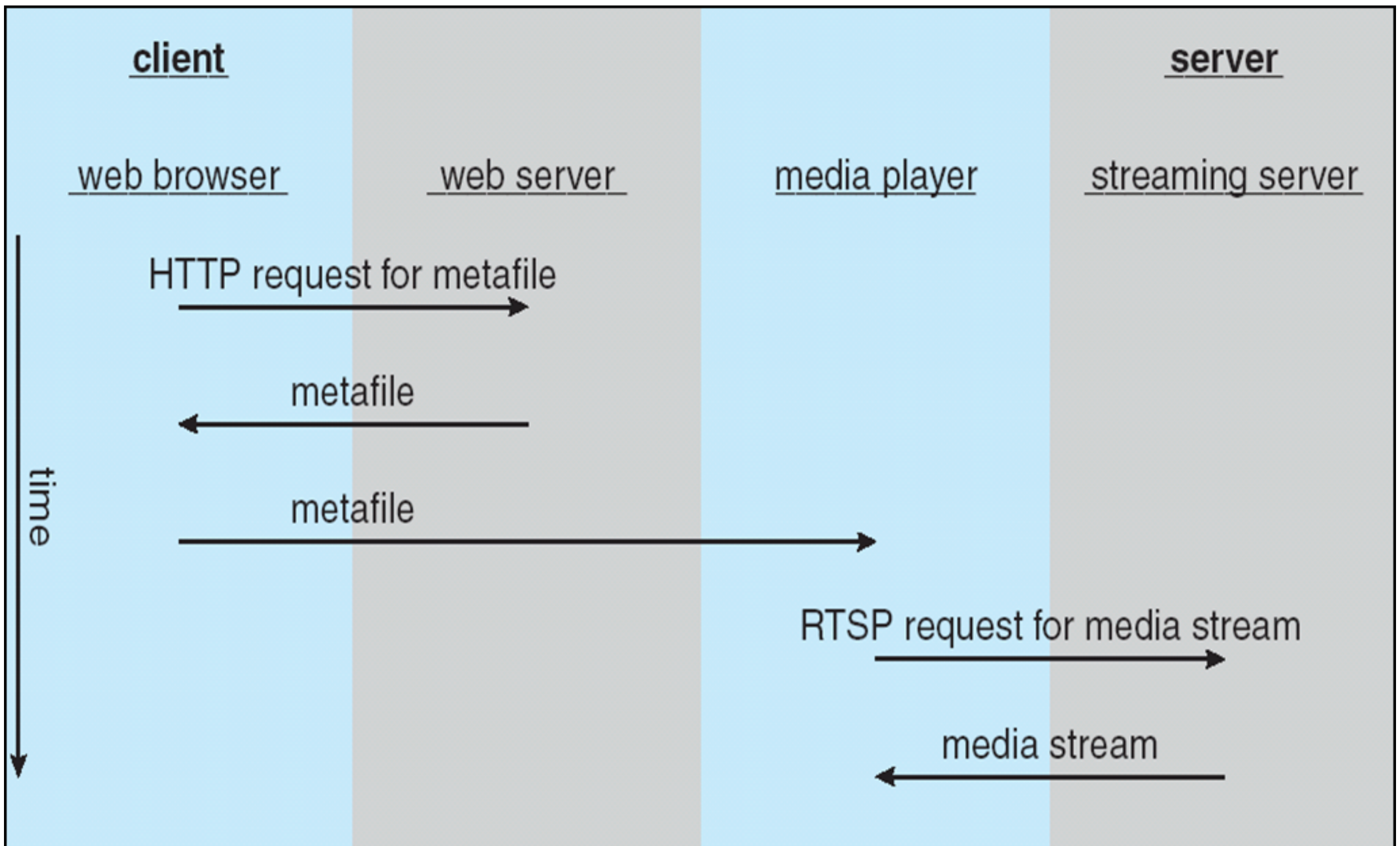


Multimedia Systems

- Network Management
- Real-Time Streaming Protocol (RTSP)
  - RTSP designed to communicate between streaming Servers and Media Players on the Client.
  - Allows Client to Pause or Seek to random positions in the stream.
  - Metafile between Server and Client delivered using HTTP.
  - Streaming media delivered from a streaming Server using RTSP commands:
    - SETUP - The server allocates resources for a client session.
    - PLAY - T server delivers a stream to a client session.
    - PAUSE - The server suspends delivery of a stream.
    - TEARDOWN - The server breaks down the connection and releases the resources allocated for the session.
  - Using RTSP instead of HTTP offers advantages related to networking issues (Using RTP for transport).

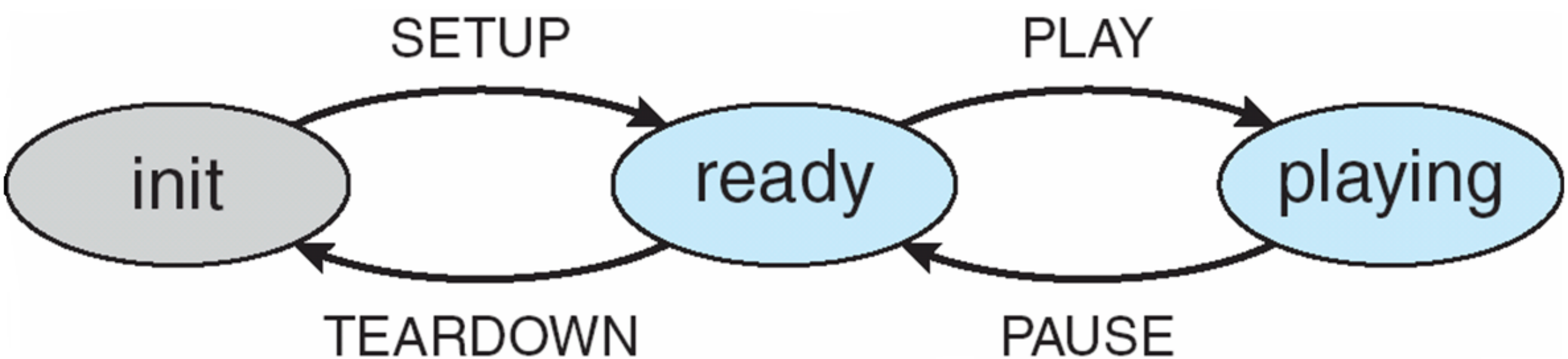
Multimedia Systems

- Network Management
- Real-Time Streaming Protocol (RTSP)

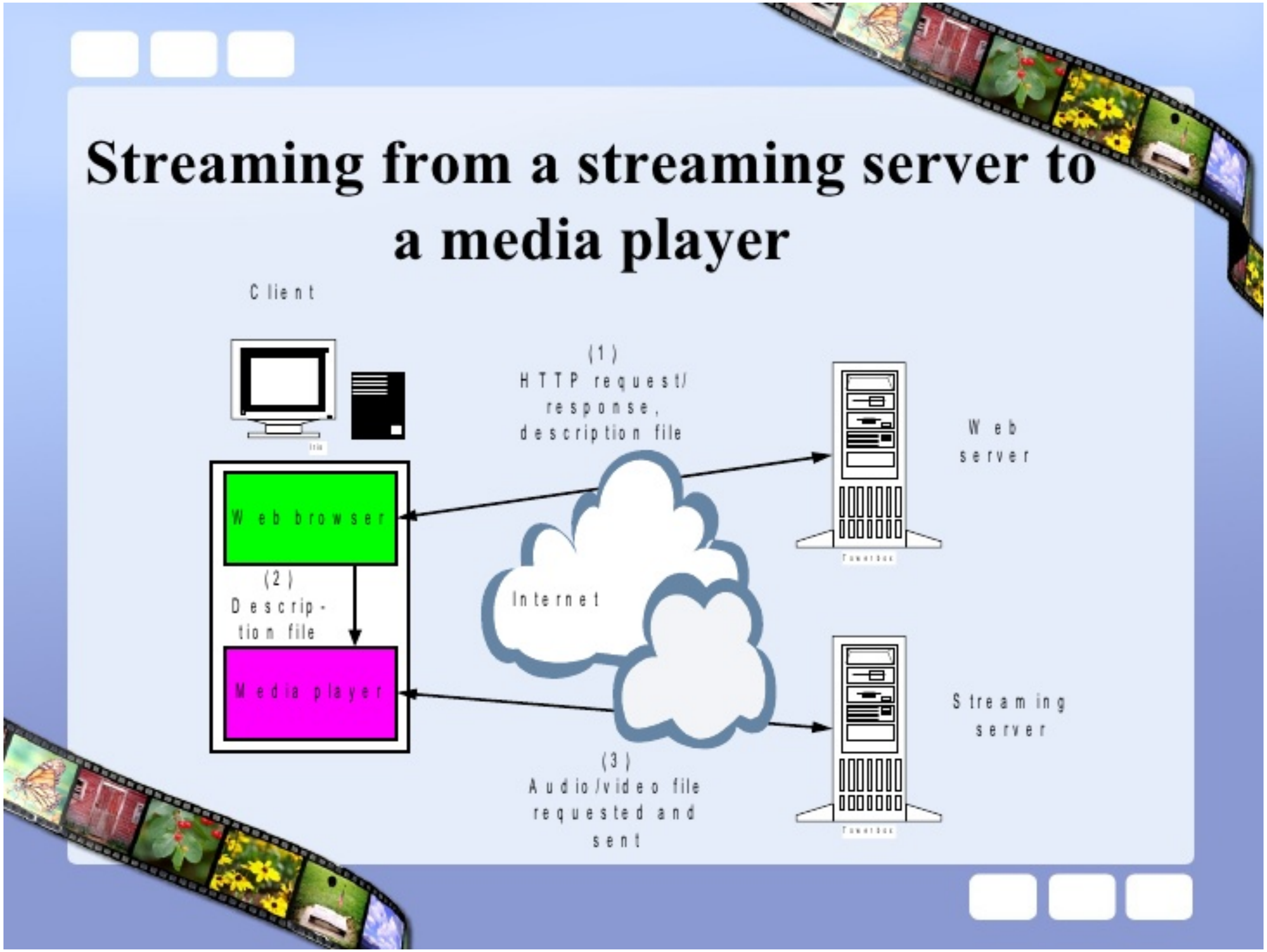


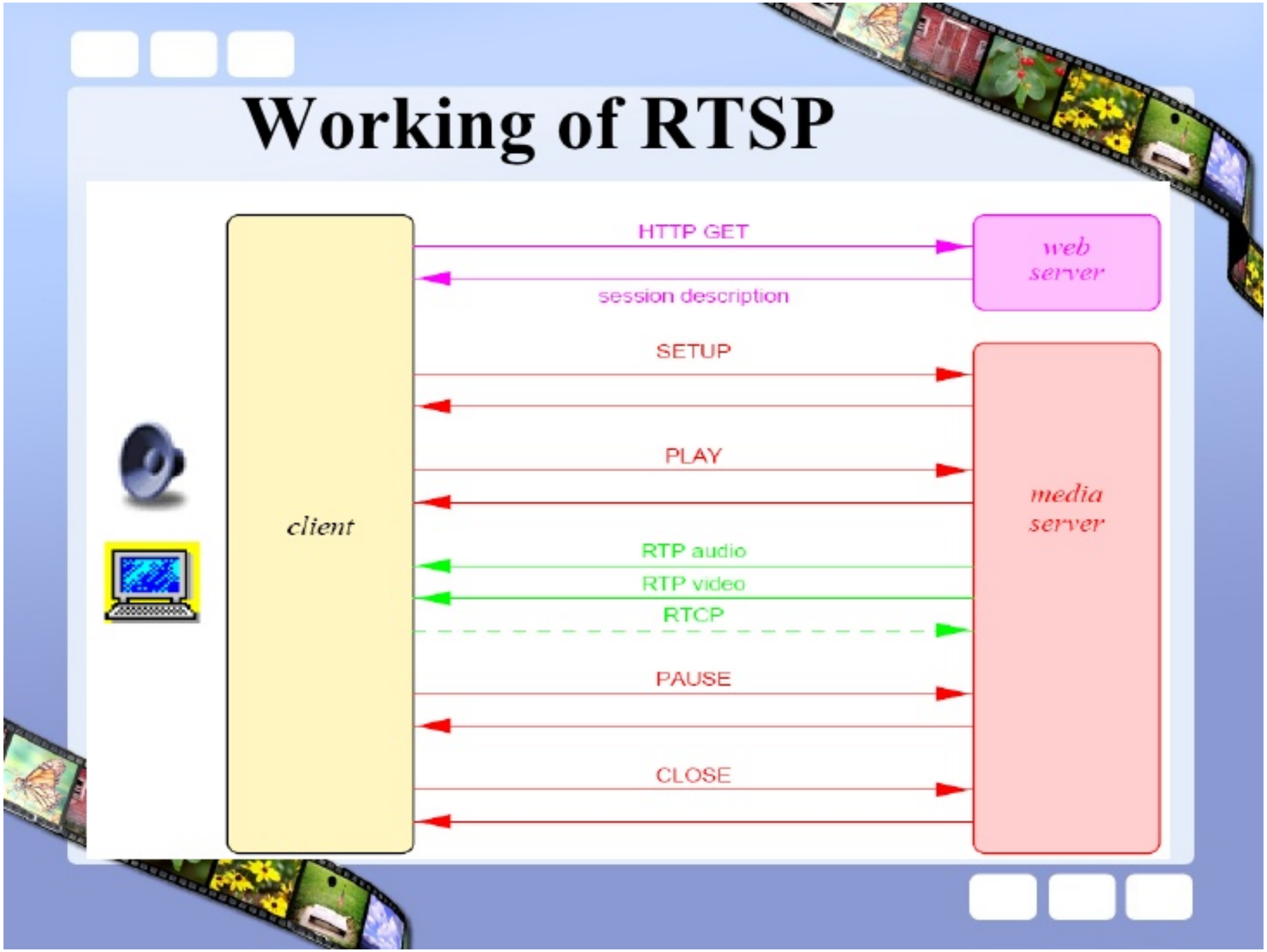
Multimedia Systems

- Network Management
- Real-Time Streaming Protocol (RTSP)
  - RTSP Server will be in following states:
    - Init, Ready, Playing
  - Transition between states occur when Server receives one of the RTSP commands from the Client.



Multimedia Systems





www.slideshare.net/esumit/rtsp

Multimedia Systems

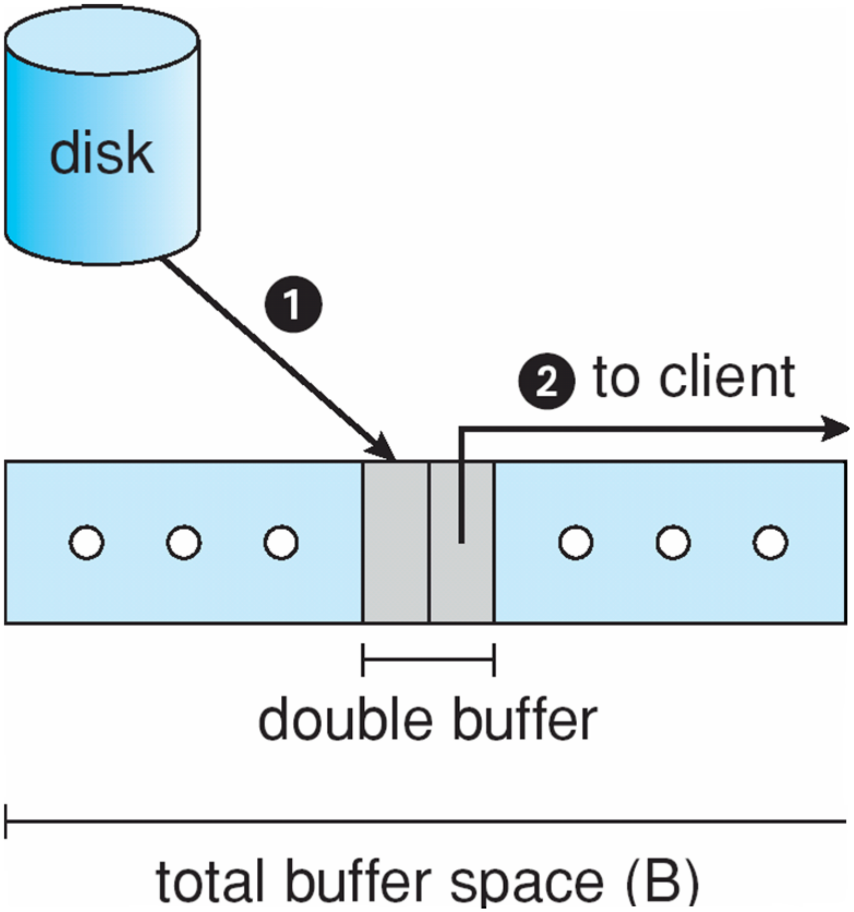
- CineBlitz Multimedia Storage Server
- High-performance Media Server supports:
  - Real-Time Clients: Continuous media with Rate requirements (video/audio).
  - Non-Real-Time Clients: Conventional data with no associated Rate requirements.
- Disk Scheduling: Services request in cycles.
  - Disk Scheduler services request in cycles.
  - At each cycle, request are placed in C-SCAN ordering.

Multimedia Systems

- CineBlitz Multimedia Storage Server
- Admission Controls provides hard QOS guarantees to meet Real-Time Client requirements.
  - Admits client ONLY if there are sufficient resources (disk bandwidth, buffer space) for data retrieval at the required rate.
  - Monitors system resources: disk bandwidth, disk latency, available buffer space.
  - Bound Requests into Service queue:
    - Service time for each request is first estimated.
    - Request is admitted ONLY if the sum of the estimated service times for all admitted request does not exceed duration of service cycle.

Multimedia Systems

- CineBlitz Multimedia Storage Server



Multimedia Systems

- Summary
- Multimedia files include video and audio files, delivered to desktop computers, PDAs, Cell Phones.
- Multimedia data have specific rate and deadline requirements.
  - Specific timing requirements require data to be compressed before delivery to a client for playback.
  - Delivered from local file system or multimedia server using streaming technique.
- Multimedia has Quality-Of-Service (QOS) requirements.
  - Multimedia systems provide QOS using Admission Control.
  - Admission Control: System accepts a request ONLY if the QOS level (rate requirement) can be meet.
  - Operating System provides CPU Scheduling and Disk Scheduling to support deadline requirements of the continuous media streaming.
  - Network Management uses RTSP/RTP protocols to handle delays and jitter caused by the Network and control the playback.