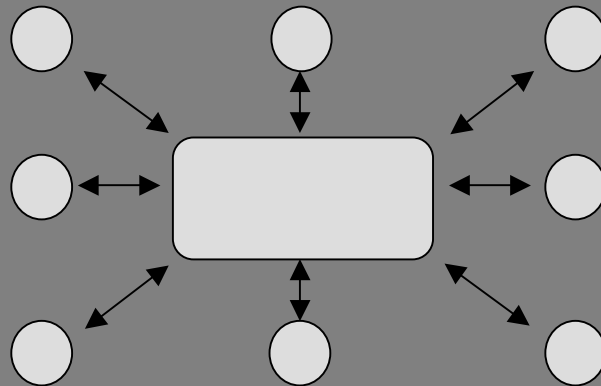


## 6. System-Architecture



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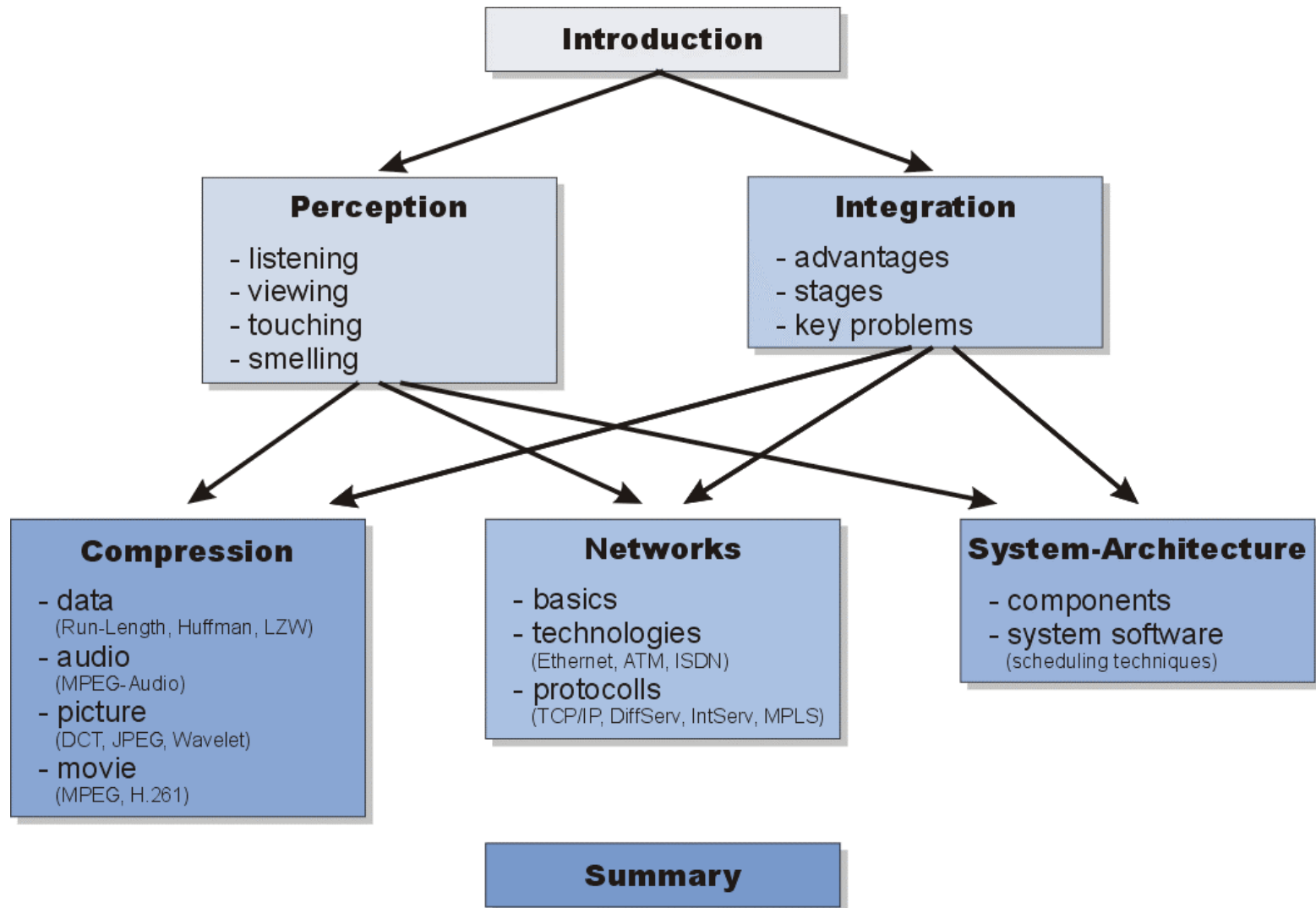
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# Site Map



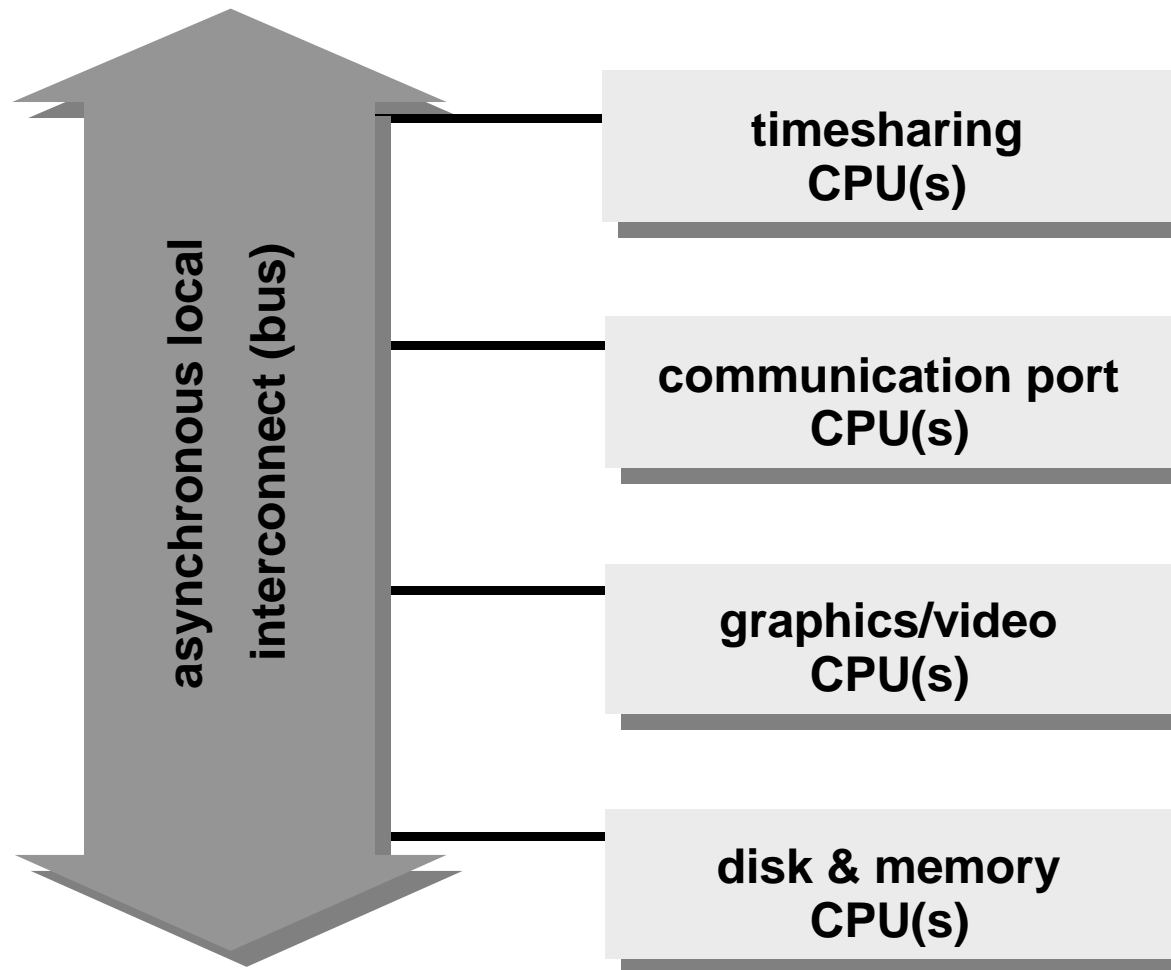
# 6.1 Hardware

## Workstation architecture

- Processors:
  - CPU for processing discrete (and continuous) media
  - Signal processors
  - Processors dedicated to graphics, audio or video data processing
- Storage:
  - Hierarchy of several levels
    - Processor / Cache
    - RAM
    - Harddisks, tapes, etc.
- Input/Output
- Communication adapter
- Busses and interfaces

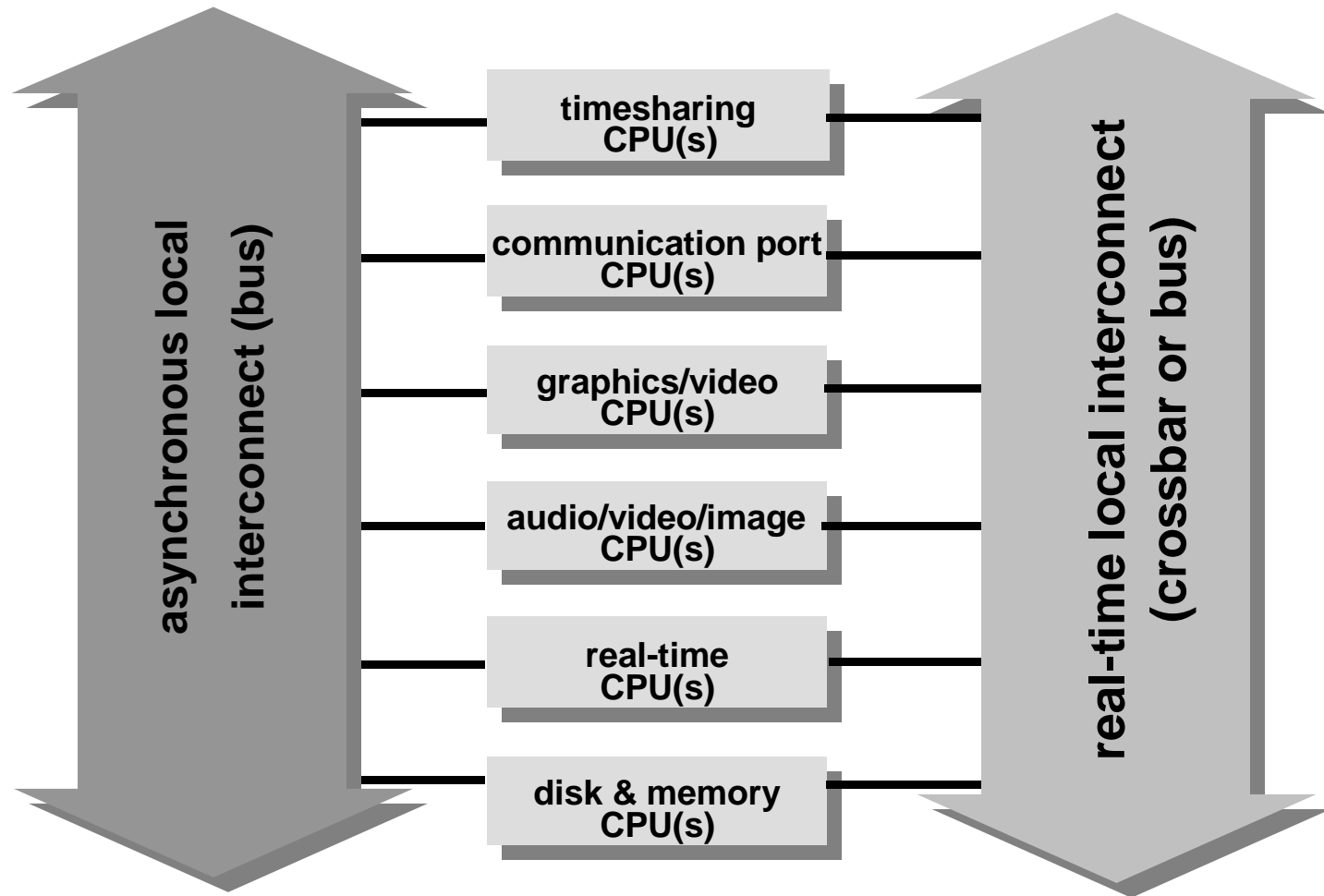
# Workstation Architecture: Today

Conventional computer:



# Workstation Architecture in the Future

Future architecture: an example





# Workstation Architecture: Switch Based

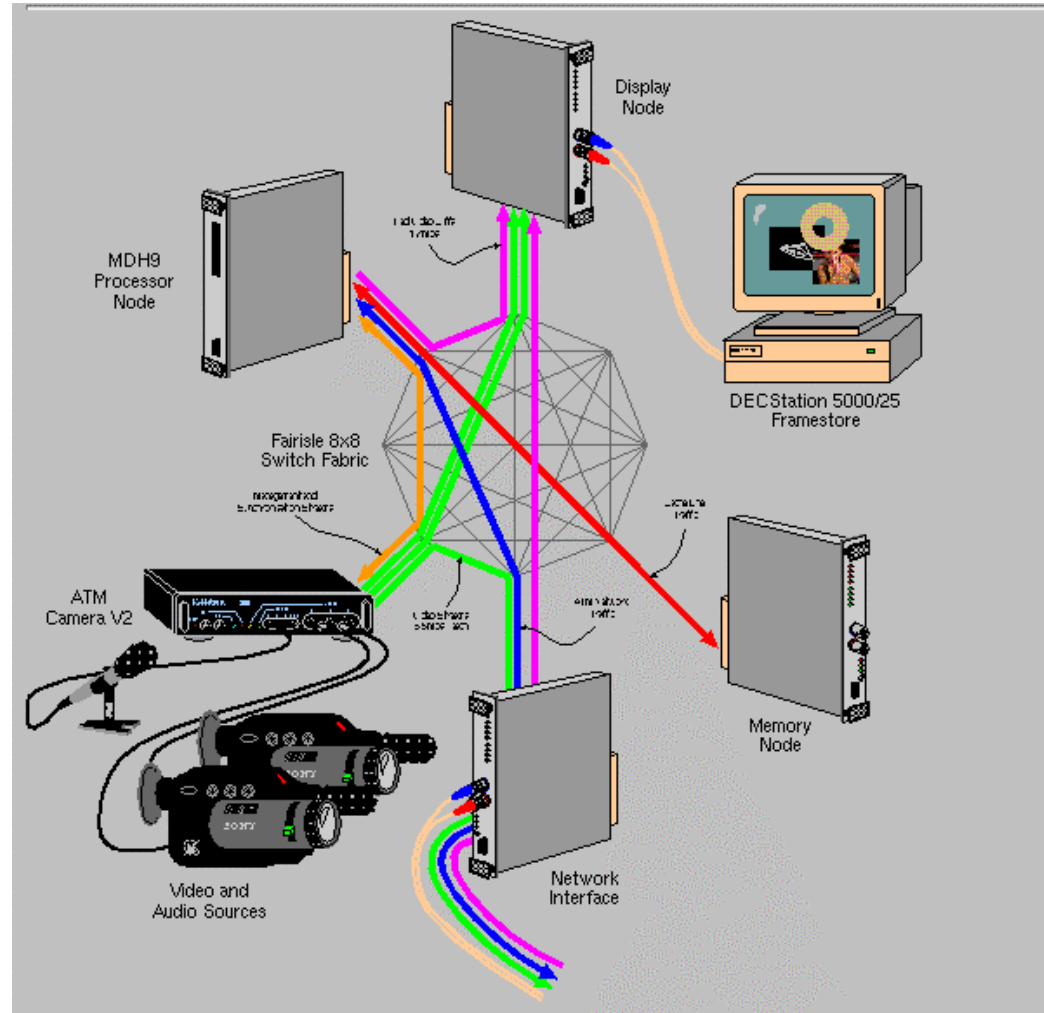
Network as interconnect for computer components:

- No bus
- Internal network
- No translation between multiplexing techniques used on bus and on external network

## ATM switch

- Internal interconnection of computer system components
- Directly connect components to high speed ATM network
- Integrates external and internal network
  - 'Everything uses ATM cells'
  - Same protocol techniques

# Workstation Architecture: Desk Area Network

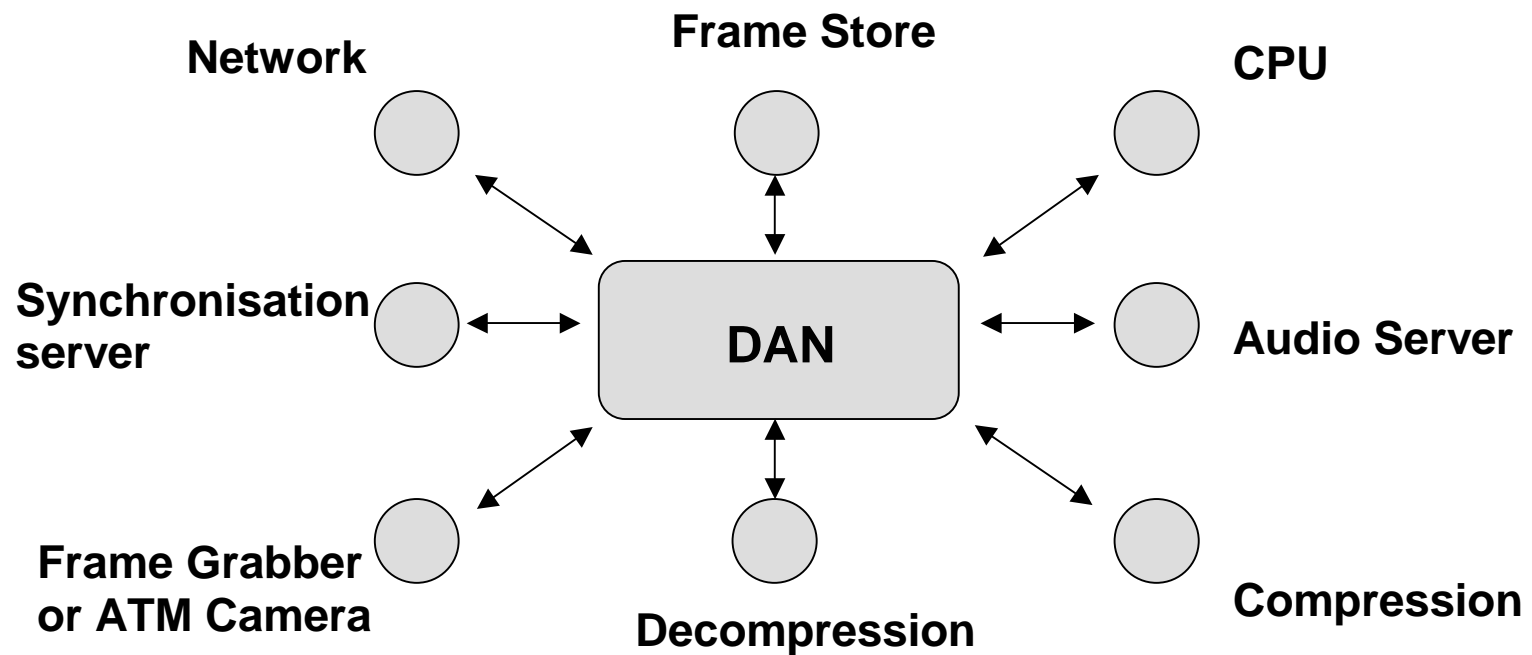


University of Cambridge U.K.

# Workstation Architecture: Desk Area Network

DAN (Desk Area Network) as multimedia workstation:

- Switch used to deliver AV streams directly to relevant devices



## 6.2 System Software

The system software provides the environment for all processes and applications

Today's widespread system software was designed to handle discrete data only

- Therefore Continuous Media is viewed as periodical and discrete data
- Logical Data Units (LDUs) of different granularity

Example:

**Film**



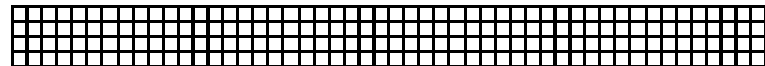
**Clip**



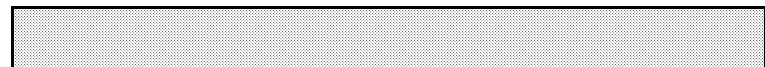
**Frame**



**Raster (8x8)**



**Pixel**

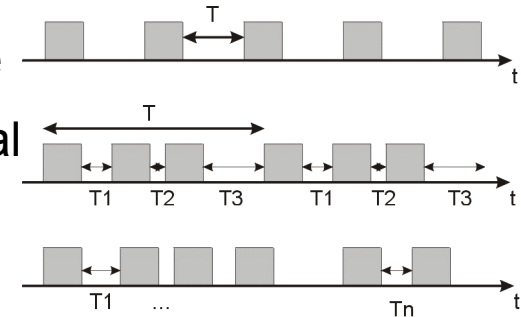


- closed LDUs: known length and number (e.g. film on a hard disk)
- open LDUs: unknown length or number (e.g. input of a camera)

# Properties of Continuous Media

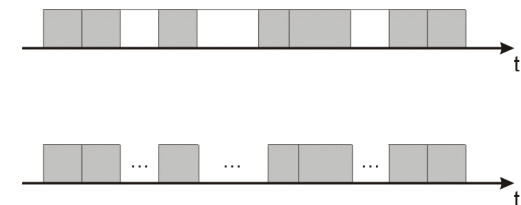
## Periodicity

- strongly periodic, fixed inter arrival time
- weakly periodic, variation of inter arrival time is fixed
- not periodic



## Joining

- joined packages, no gap between packages ( $\Rightarrow$  strongly periodic)
- not joined



## Size

- strongly regular size, all packages have the same size
- weakly regular size, variation of package size is fixed
- irregular

# System Software Tasks

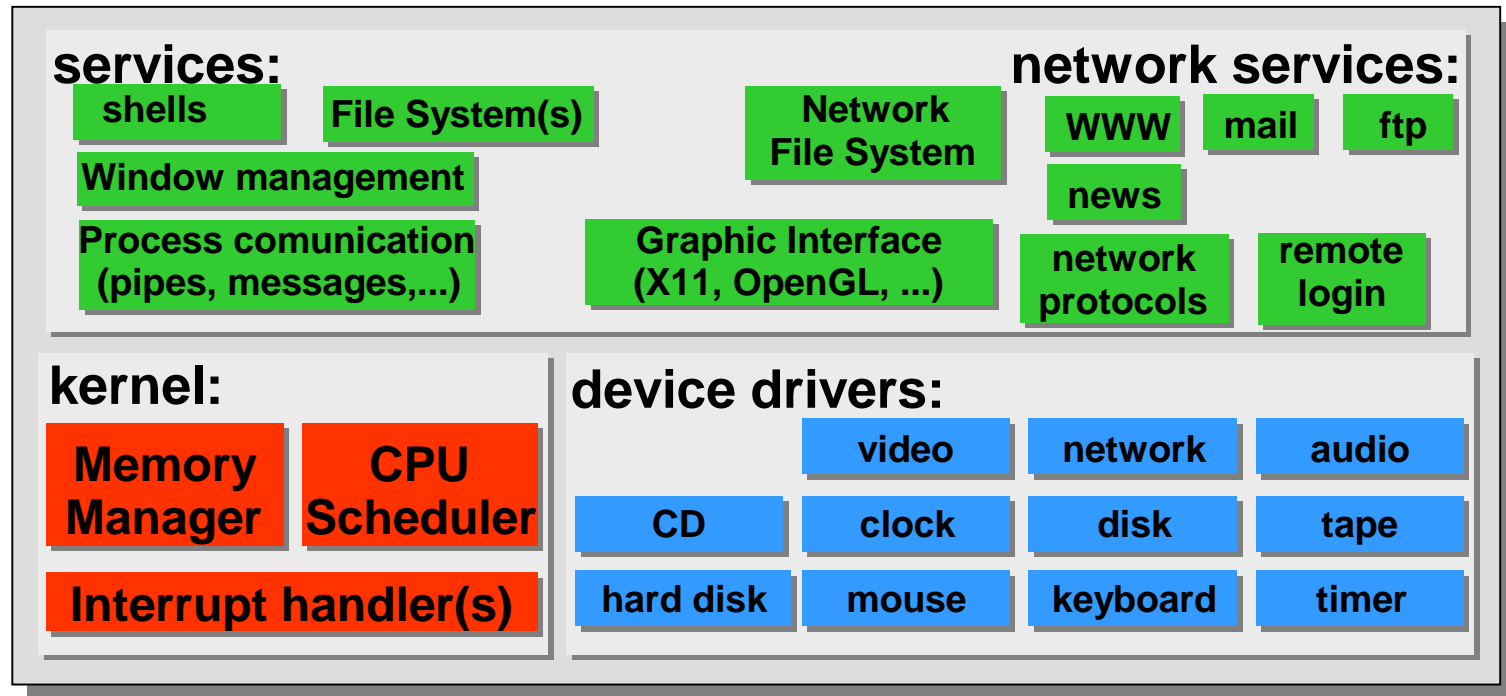
## Typical tasks:

- Provide an interface to the rest of the world for processes
  - Access to I/O devices
  - Abstraction of hardware
  - Inter-Process communication and synchronization
- Operation of hardware
  - Prepare data for hardware components
  - Control the hardware and respond to interrupts
- Organize the storage of data on harddisks, tapes, etc.
- Management of access to system resources (memory, CPUs, storage media, network, other I/O devices)
  - When to access
  - Who is allowed to access
  - Reservation of resources
- More ...

System software should fulfill all tasks with respect to the time requirements of continuous media processing

# Examples: System Software Tasks

**Applications**  
(Video Conference, CD player, word processor, ...)



**Hardware**  
(memory, CPU(s), system bus, devices)

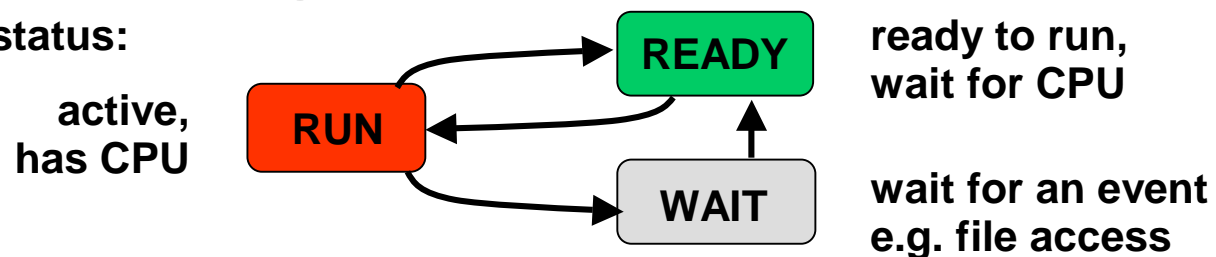
# Management of CPU access

Multitasking allows several processes (applications or services) to run concurrently

- several processes compete for resources
- Assign a CPU for a short time (e.g. 10 ms) slices to a process

Process scheduling:

Process status:



Components:

- Scheduler: planing order of processes
- Dispatcher: assign a new process to a CPU



# Process Scheduling

Processes are assigned to a CPU according to a specific scheduling strategy

- The strategy should be fair
  - Each process gains access to a CPU sooner or later
  - Priorities define how often, how soon and how long a process is assigned to a CPU
- Different strategies could be applied to classes of processes
- Further details <http://www.wagss.informatik.uni-kl.de/Lehre/BS9900/>

Example scheduling in Windows NT:

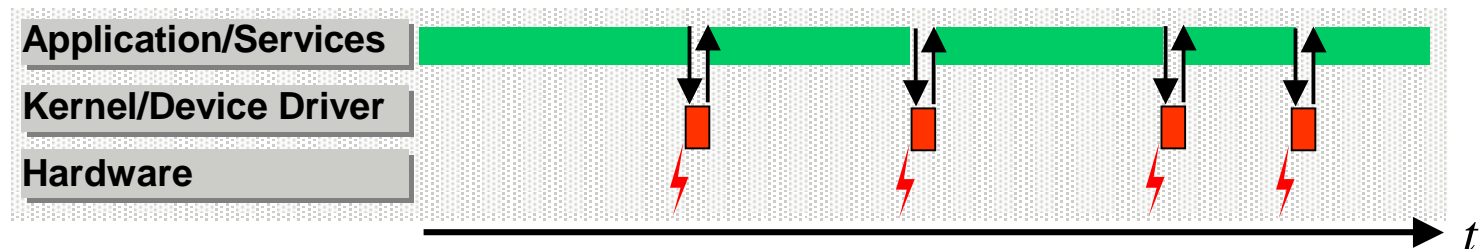
- Scheduling priorities depend on process + thread priorities
- Processes of the modes IDLE / NORMAL / HIGH are scheduled by a fair strategy
  - Process priorities are raised and lowered dynamically to implement fairness
- REALTIME modes processes are assigned to the CPU in order of precedence
  - A REALTIME process may block the whole system
  - This mode is usually used for few system processes only

Thread \ Process	IDLE	NORMAL	HIGH	REALTIME
TIME CRITICAL	15	15	15	31
HIGHEST	6	10	15	26
NORMAL	4	8	13	24
LOWEST	2	6	11	22
IDLE	1	1	1	16

# Interrupts

Interrupts are handled by the kernel and device drivers:

- about 1000 Interrupts per second must be handled, i.e. about 100 within a typical time slice
- The utilization of a time slice depends on
  - The number of interrupts
  - The required processing time for each interrupt

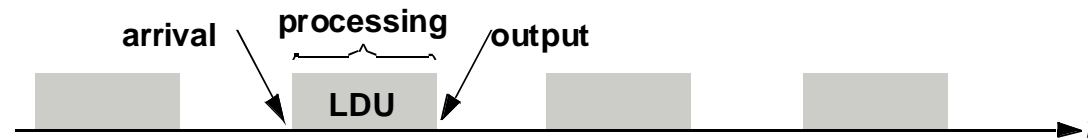


# Problems of Continuous Media processing

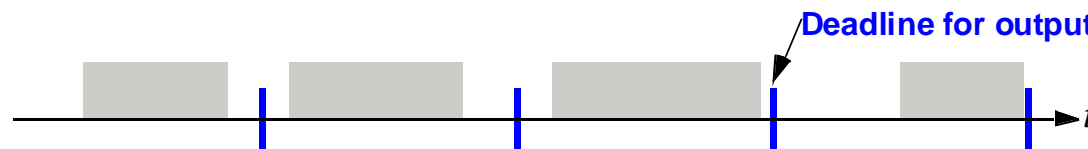
Irregular behavior of applications makes periodical processing of continuous media difficult, especially for real-time communication

Consider the arrival, processing and output time of an LDU:

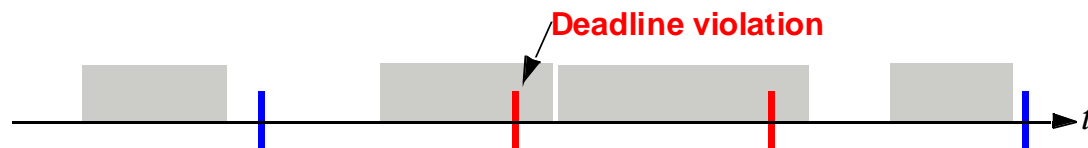
- Ideal: regular arrival and constant processing time, leads to regular output



- Acceptable: limited variation of arrival and processing time



- Not acceptable: increased delay or jitter leads to deadline violation



# Real-Time Systems

Real-time processing means, it can be guaranteed that the processing results are available within a given time interval.

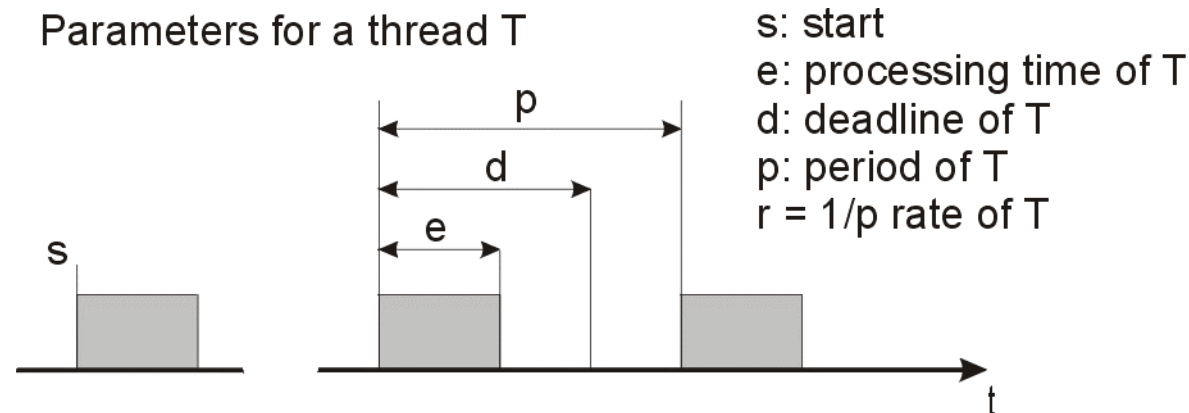
Properties of Real-Time systems:

- The processing time for all system components must be predictable
- Reservation of all types of resources must be possible
- Short response time for time critical processes
- The system must be stable at high load

Real-time systems are typical used for controlling industrial processes or electronic controls in cars or airplanes

Real-Time systems are much to restrictive to be used as a basis for multimedia systems.

# Real-Time Scheduling Principles



## Components for real-time scheduling:

- CPU-Broker: test if a new real-time process could be accepted, based on scheduling rules
- Scheduler: determine order of processes, e.g. by priorities
- Dispatcher: assign process to CPU
- Problem: parameters often not known in advance, but measuring parameters at run-time requires restart of CPU-Broker  $\Rightarrow$  no guarantees

## Distinguish

- Realtime processes (RT-Processes) with explicit time requirements
- Timesharing processes (TS-Processes) having best effort requirements

# Earliest Deadline First (EDF)

From a set of process select the process with the earliest deadline

- processes must be preemptive
- EDF is optimal, i.e. if there is a schedule for a set of RT-processes to meet their deadline, then EDF will find it
- EDF is dynamic, i.e. there is no fixed schedule plan for all processes
  - EDF could be used even with varying  $e$  and  $d$
  - EDF has a complexity of  $\theta(n^2)$
  - when used with an priority controlled scheduler, then EDF requires often a rearrangement of all process priorities
- process that can not meet their deadline are recognized and can be removed/skipped ( $\Rightarrow$  avoid overload)

## Another scheduling strategy

- Shortest Job First (SJF)
  - May be static or dynamic
  - Guarantees that as many processes as possible keep their deadline

# Rate Monotonic Planning

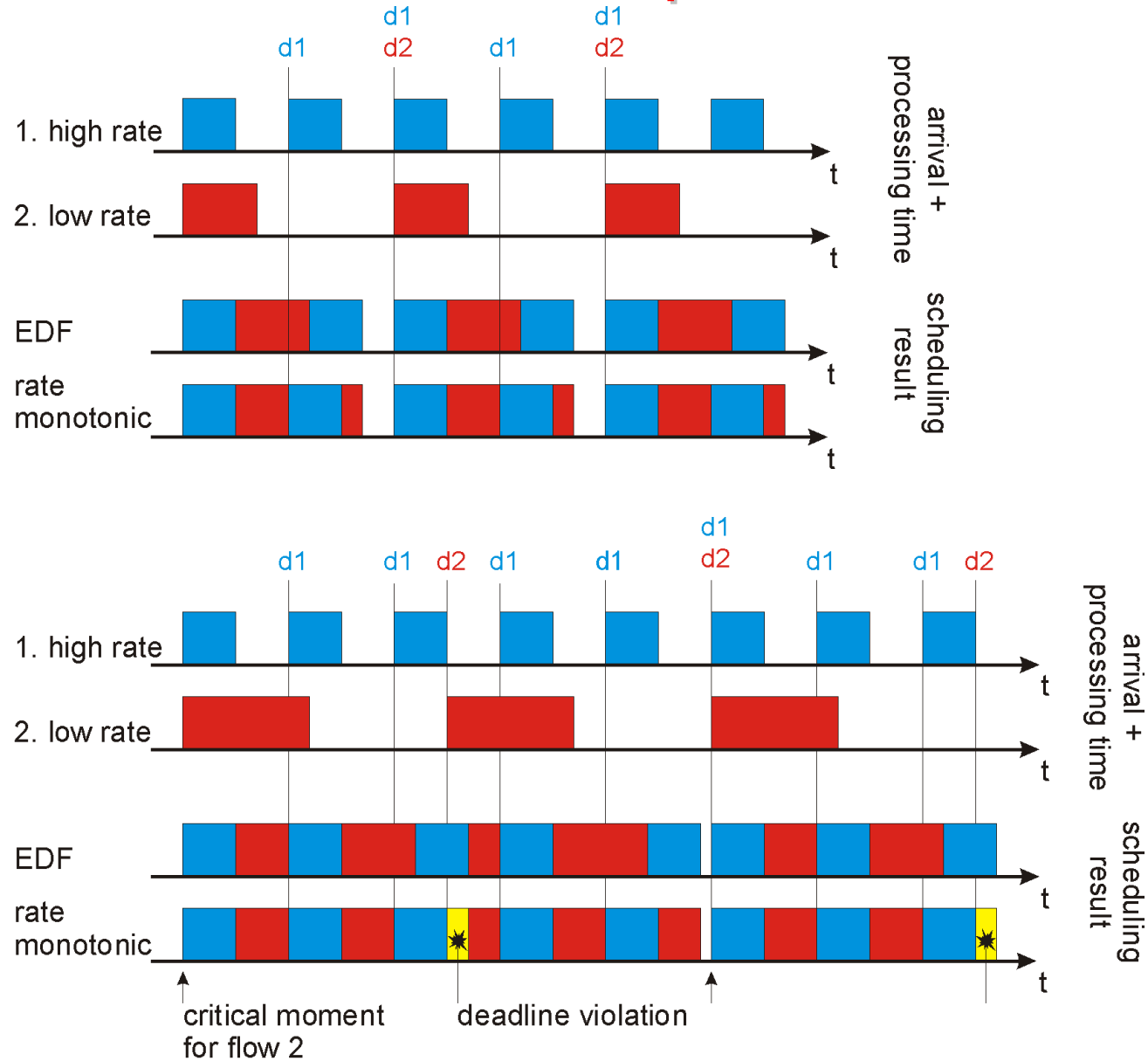
Process priorities are related to the rate, the higher the rate the higher the priority

- Rate Monotonic Planning is an optimal static method. Static means a process a plan is made only once.
- Necessary assumptions:
  - All real-time processes are periodic
  - Deadline equals to the beginning of the next period ( $d = p$ )
  - Processes are independent to each other
  - $e$  is fixed
  - Processes are preemptive
- It is guaranteed that a process always keeps its deadline if this is true in a period after a critical moment
  - The critical moment (or worst case) for a process is when at the beginning of its period all other processes with a higher priority also start their period

Another scheduling strategy

- Monotonic planning according to difference between deadline and arrival time
  - Could be used if the deadline is earlier than the beginning of the next period

# Examples





# Scheduling Extensions

## Support of non periodic processes

- Add virtual LDUs to create a periodic behaviour
  - Useful if a process is nearly periodic
  - Inefficient resource usage
- Reserve a CPU budget for non periodic processes, the budget is refreshed periodically

## Administrative mechanisms

- Early recognition of deadline violations
  - Easy to implement for EDF
- Stop some low priority processes if deadlines are violated continuously
- Measurement of thread parameters during run time
  - Requires a renew of the scheduling plan even for static strategies

# Dispatcher (1)

## Generation of dispatching tables

- A dynamic scheduler determines only the next (few) table entries
  - The scheduler may produce significant overhead
- A static scheduler determines one table that is valid for each period also called reservation table

...	...
$t_n$	Process 330
$t_{n+1}$	Process 331, 332
$t_{n+2}$	A TS-Process
...	...

$t_0$	Process 330
$t_1$	Process 331, 332
$t_2$	Process 330
$t_3$	A TS-Process

## Meta scheduler (priority scheduling)

- Use the normal system scheduler and dispatcher
- Additionally use a meta scheduler to plan RT-Processes + wildcards for TS-Processes
- A meta dispatcher changes the priorities of the RT-Processes according to the meta scheduler
  - Starting a RT-Process: increase its priority to a high level
  - Starting a RT-Process requires to run the meat dispatcher first
  - Stopping a RT-Process: decrease its priority to a low level
  - TS-Processes may run if all RT-Processes are stopped
  - The meta dispatcher must have the highest available priority

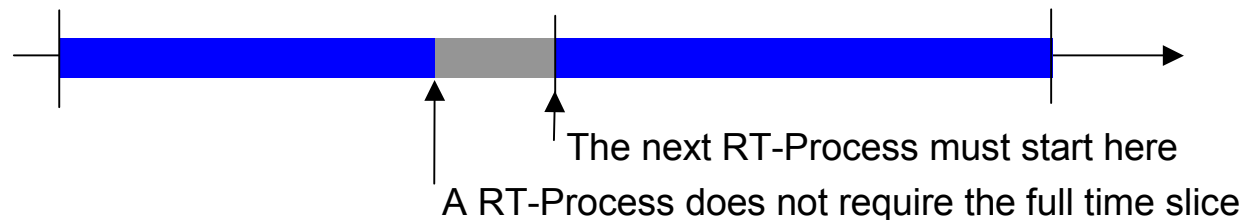
# Dispatcher (2)

## Problems with static dispatching tables

- The processing time  $e$  must be known exactly
- What happens if a RT-Process starts at  $t_n$  but the next LDU is available at  $t_n + \epsilon$



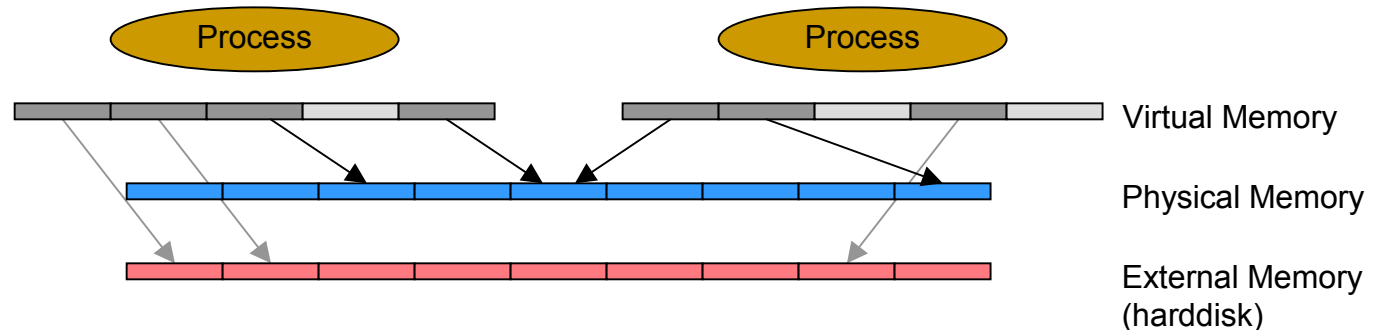
- If a RT-Process does not require its full time slice and the next process is also a RT-Process, then the gap between those two processes can not be used efficiently



- LDUs can not be processed as soon as they are available, this leads to additional delay. Particularly when several RT-Processes are involved in handling one media stream.

# Management of Memory access

## Memory management principle



- The whole memory is divided into pages
- Each process has its own virtual address space
- Virtual addresses are mapped to physical addresses by an Memory Management Unit (MMU)
- The physical memory is extended by external memory
  - Seldom used pages are written to harddisk in order to increase the available physical memory
  - If external memory is accessed then the MMU causes an interrupt and the system software has to load the page into physical memory

# Aspects for Multimedia Systems

All media data and program code must be in physical memory

- Some systems allow direct access to physical memory
- Usually pages can be locked to avoid copying to external devices
  - If too much pages are locked then the system performance is reduced significantly

Use shared memory to avoid copying of data

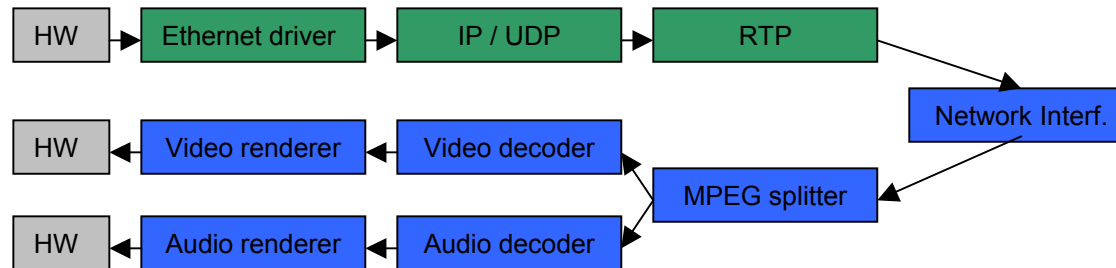
- Synchronization for memory access is required
- Use double buffering (or multiple buffers) for reader/writer relations in order to support parallel processing of different LDUs

Avoid allocation of memory at run time

- Memory allocation is a complex task and may increase the processing time unnecessarily
- The time need for memory allocation is (in general) unpredictable

# Buffer Management

Example for components involved in real time media processing



Each arrow means transportation of data from one modul to another via buffers

## Buffer management techniques

- Copying data
  - Each modul has its own buffers
  - Data is copied at the interfaces of a modul
- Offset management
  - There is one big buffer of shared memory with offsets pointing to segments for each modul
  - The sum of the maximum required buffers of all moduls must be known
- Distribution and collection
  - Each modul has its own buffers of shared memory
  - A table of pointers is exchanged at the interfaces (may be shared memory)
  - When sending data the last component has to collect the data, i.e. copy it into a single PDU

# Managemet of Disk access

Today single harddisks are fast enough to deliver few media streams in time

A throughput of 100 Mbyte/s is (theoretically) sufficient to deliver 200 MPEG-2 videostreams of 4 Mbit/s

The problem:

- Random access to different media streams prevents sequential reading of data
- The access time becomes the bottleneck

The solution:

- The bandwidth of streamed media is much smaller than the throughput of the harddisk and there are medium delay requirements when there is only a human to machine interaction
- Buffer of large data segments and realize a smooth streaming from memory only, this reduces the number of disk accesses

# Increasing Harddisk Throughput (1)

RAID = Redundant Arrays of Inexpensive Disks  
aims to increase throughput and/or reliability

## RAID-0

- Data may be distributed over several hardisks

## RAID-1

- All data are written twice, i.e. there is a mirror for each harddisk
- Low efficiency

## RAID-2

- Hamming-Codes are written instead of complete mirrors
- Higher efficiency than RAID-1 but more complex because of Hamming-Code calculation

## RAID-3

- The bits are distributed over several harddisks using only one additional harddisk for a parity bit
- Since the harddisk controller is able to detect corrupted disks, the parity bit can replace any bit



# Increasing Harddisk Throughput (2)

## RAID-4

- Calculates a parity block for so called stripes
- A stripe consists of one or more stripe units, each unit is written to one disk, so that a stripe is distributed over several disks. Except for small data units which are smaller than a stripe unit.

## RAID-5

- The throughput of dedicated disks for parity data is the throughput bottleneck
- Like RAID-4 but the parity blocks are also distributed over several disks

## RAID-6

- Like Raid-5 but a more sophisticated parity calculation (Reed-Solomon) can handle the drop out of two harddisks

Parallel access of several disks (RAID-3 to 6) improves the overall throughput

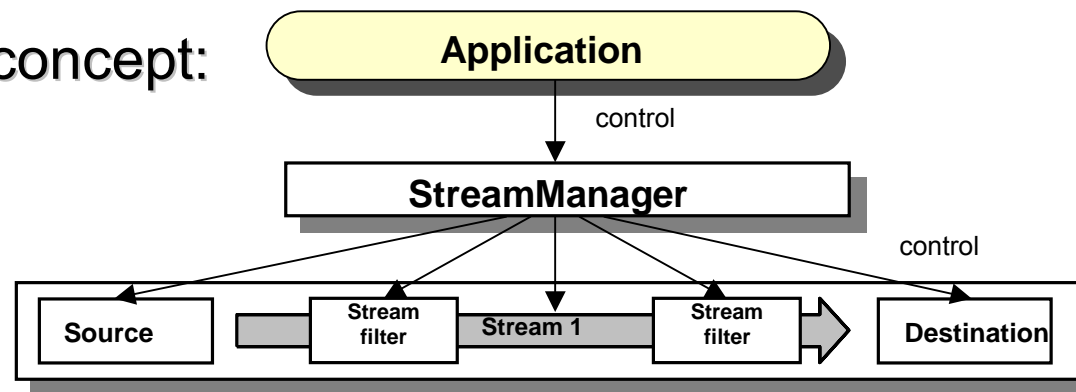
## 6.3 Application Software

How to handle continuous media within applications?

Requirements:

- Periodic processing of data
  - In most cases the application only needs to control the presentation
  - Usage of external moduls/libraries for media processing, e.g. coding/decoding
- ⇒ Use an external component for media processing, which is controlled by the application only

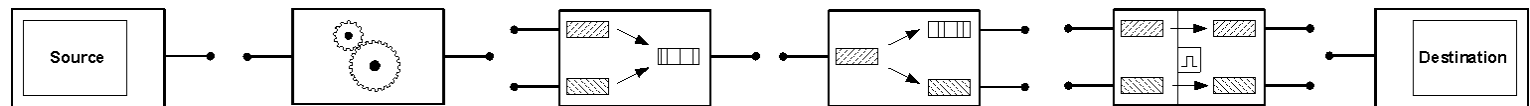
Stream concept:



# Stream concept

## Realization

- Special threads within the application context or even special processes
  - Using threads avoids inter process communication with the „main“ application (e.g. DirectShow from Microsoft)
  - Using processes to apply real-time schedulers
- There are different types of stream-filters



## Advantages

- A well defined stream-filter interfaces enables adequate buffering strategies
- Simple reuse of software componets
- Easy handling for applications

## Disadvantages

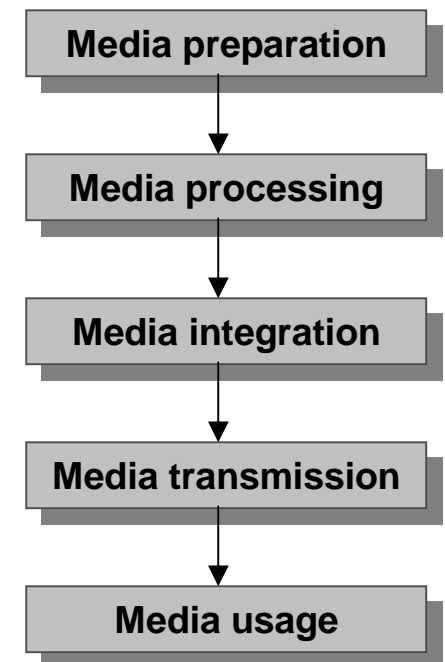
- If special data processing is required the application programmer must supply a new strem-filter

# Classification of Multimedia Applications (1)

There is no common classification for multimedia applications

One classification approach considers the life time of media

- Media preparation: digitization of real objects
  - Digitization of audio and video
  - Scanning texts and graphics
  - Registration of 2D or 3D movements
  - Recognition of smells
- Media processing: modification of digitized media and adding of other digital information
  - Word, image and graphic processing
  - Audio and video processing
  - Creation of animations



# Classification of Multimedia Applications (2)

- Media integration: relate different media to each other
  - Hypermedia / hypertext editors
  - Authoring tools
- Media transmission: transportation of media to the user
  - Interactive services
    - Conversation services
    - Message transmission (human to human only, like chat)
    - Tele activity services, i.e. do something in the distance (online banking, access to databases, control machines, ...)
  - Distribution services
    - Push services (distribution of news, share prices, ...)
    - Video and audio broadcasting
    - Video and audio (nearly) on demand
- Media usage: consuming media
  - Electronic books and magazines
  - Kiosk systems
  - Tele-Shopping
  - Virtual reality
  - Entertainment
    - (Interactive) video and audio
    - Computergames
  - Education
  - ...