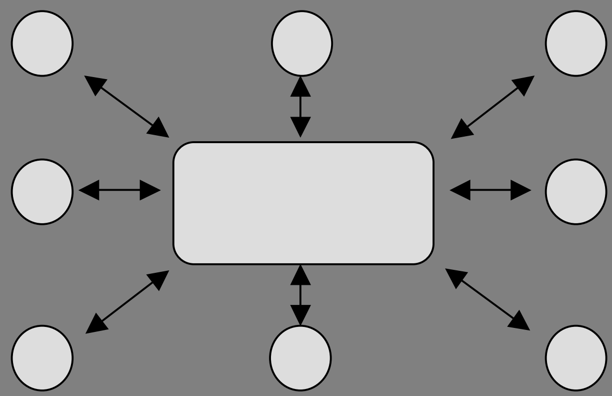
Integrated Communication Systems

Multimediale Visualisierungssysteme
WS 2000/2001

ICSY

6. System-Architecture



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AG: Integrierte Kommunikationssysteme

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Literatur

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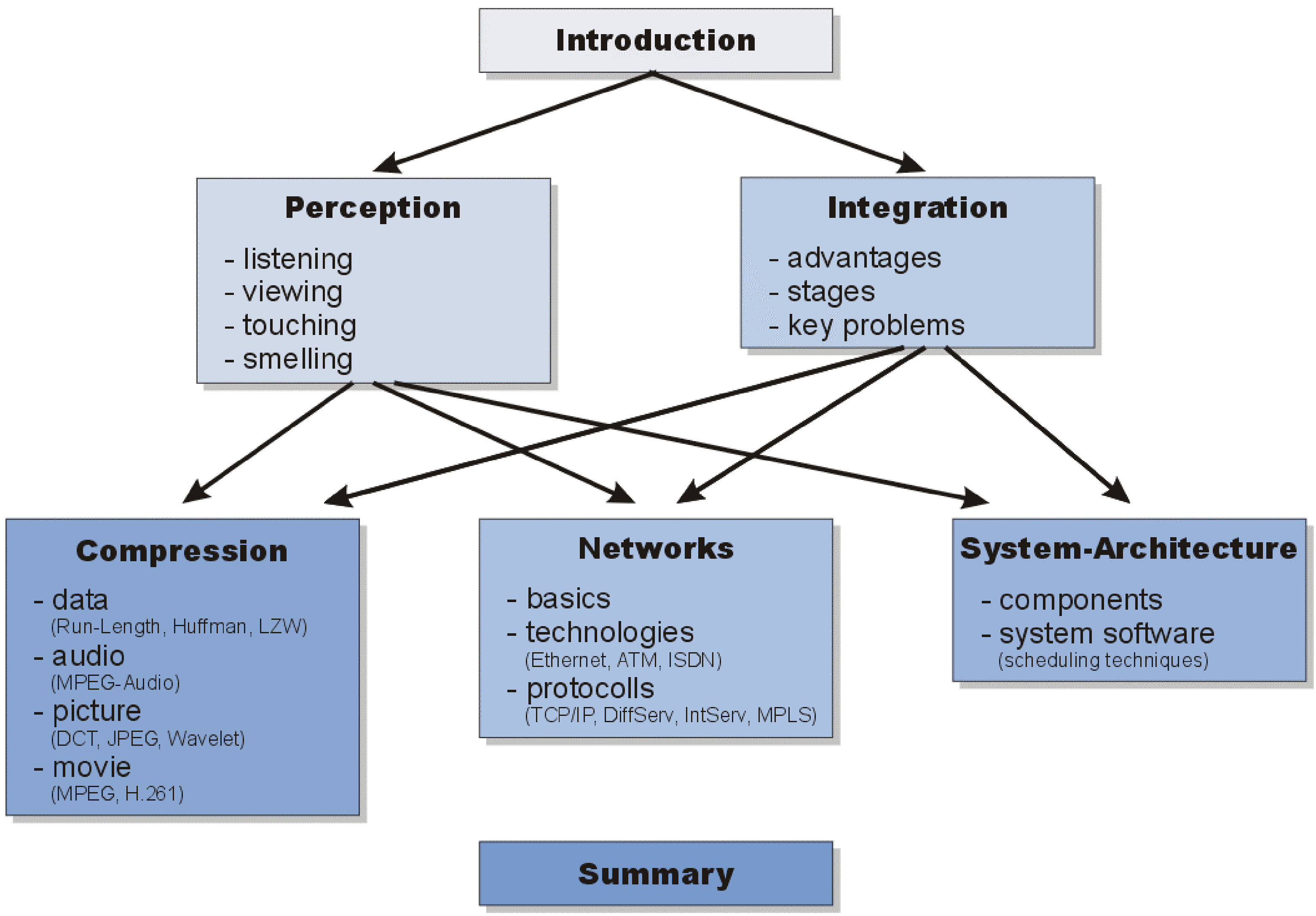
Site Map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System-Architecture
- components
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(scheduling techniques)
Summary

6.1 Hardware

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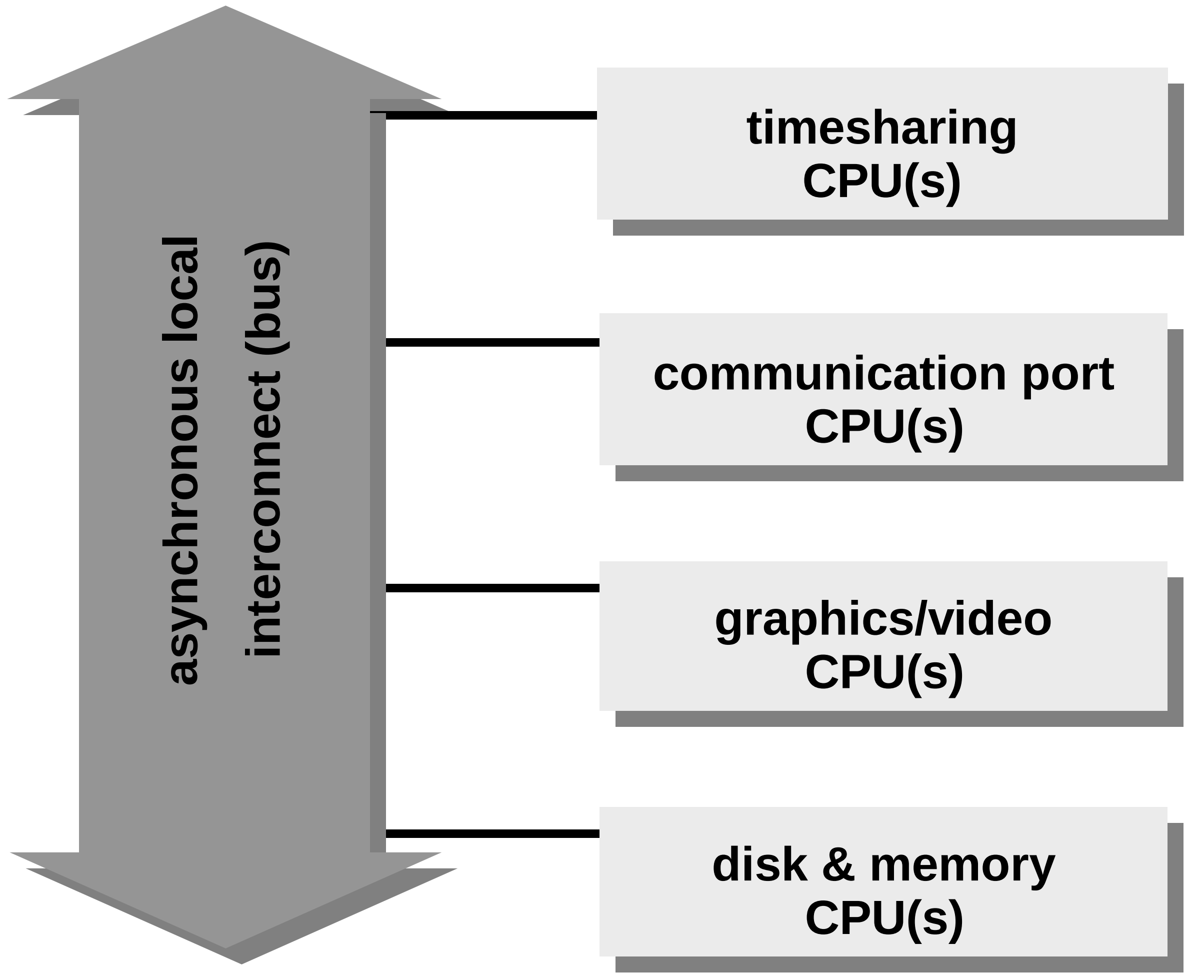
Workstation architecture

- 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

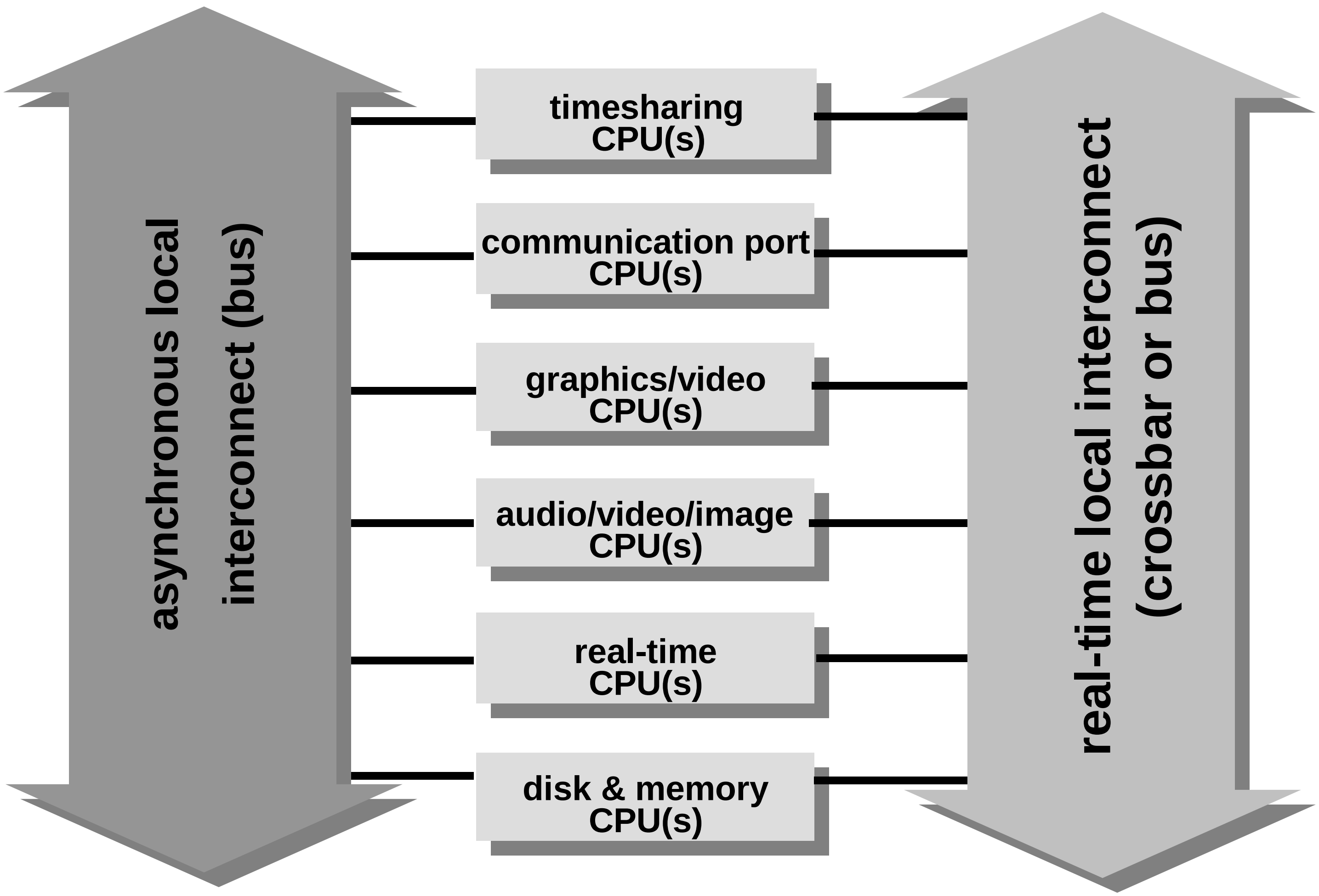
Workstation Architecture: Today

Conventional computer:



Workstation Architecture in the Future

Future architecture: an example



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Workstation Architecture: Switch Based

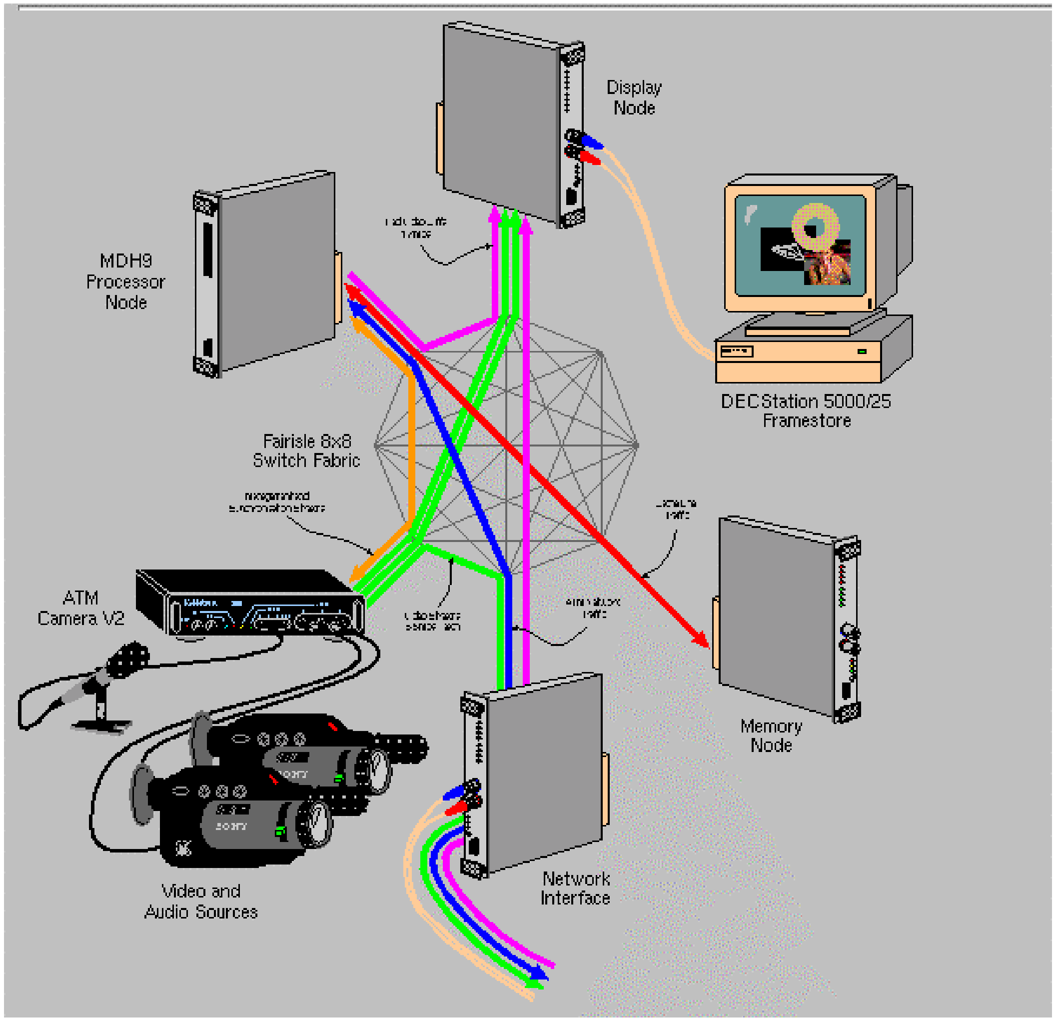
Network as interconnect for computer components:

- 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

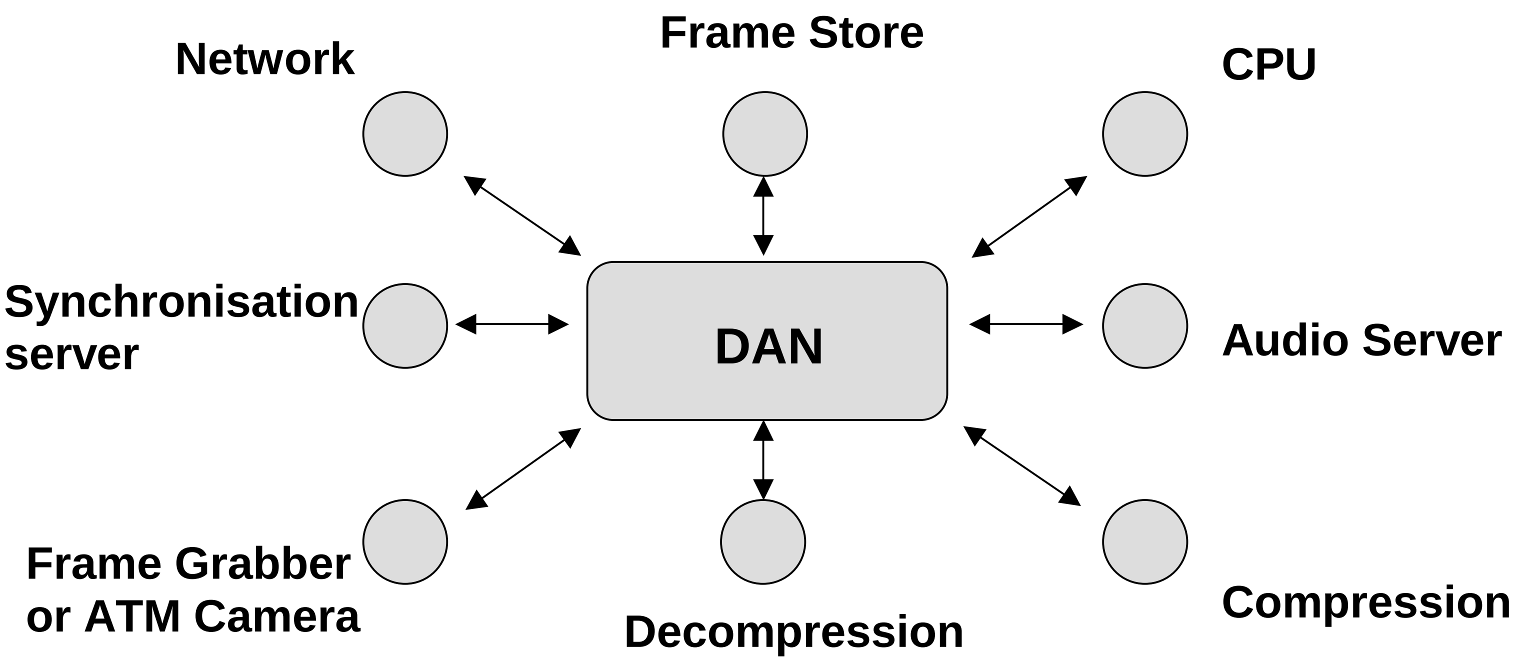


University of Cambridge U.K.

Workstation Architecture: Desk Area Network

DAN (Desk Area Network) as multimedia workstation:

– Switch used to deliver AV streams directly to relevant devices

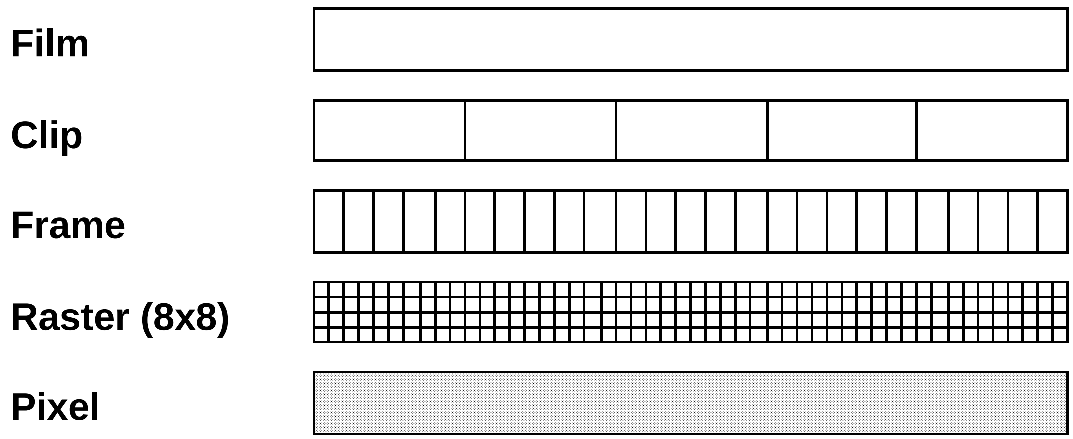


6.2 System Software

The system software provides the environment for all processes and applications

Todays widespread system software was desgined to handle discrete data only

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

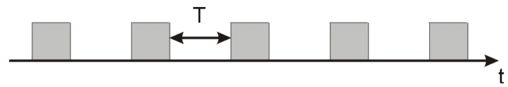


  - closed LDUs: known length and number (e.g. film on a hard disk)
  - open LDUs: unknown length or number (e.g. input of a camera)

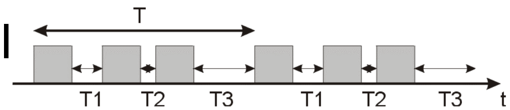
Properties of Continuous Media

Periodicity

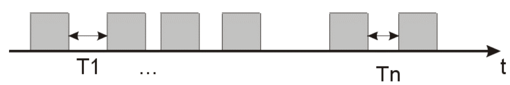
– strongly periodc, fixed inter arrival time



– weakly periodic, variation of inter arrival time is fixed

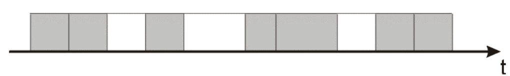


– not periodic

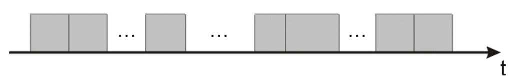


Joining

– joined packages, no gab between packages (⇒ strongly periodic)



– not joined



Size

– strongly regular size, all packages have the same size

– weakly regular size, variation of package size is fixed

– irregular

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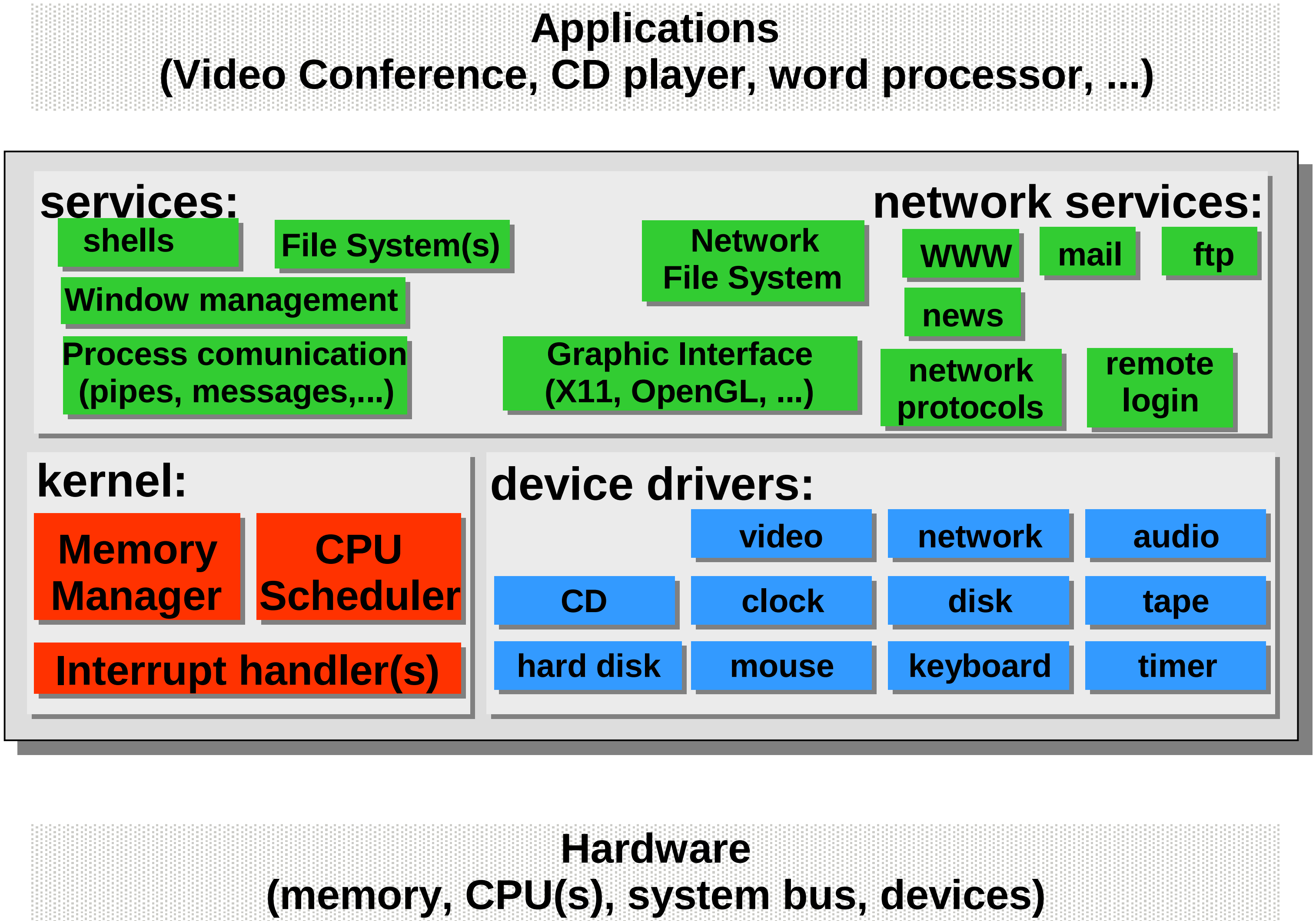
System Software Tasks

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 ressources
- More ...

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

Examples: System Software Tasks



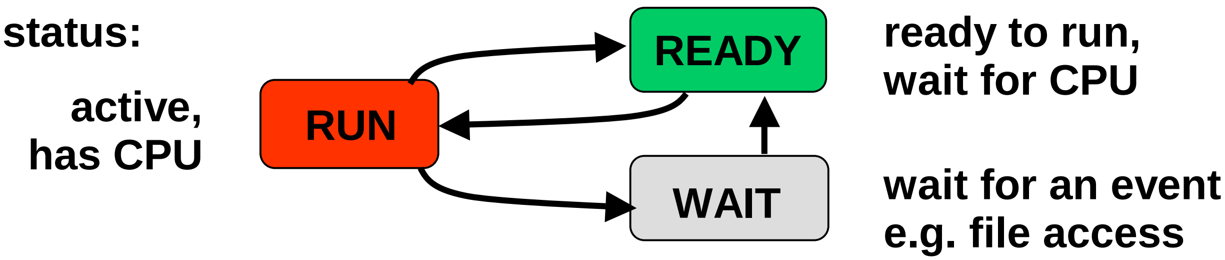
Management of CPU access

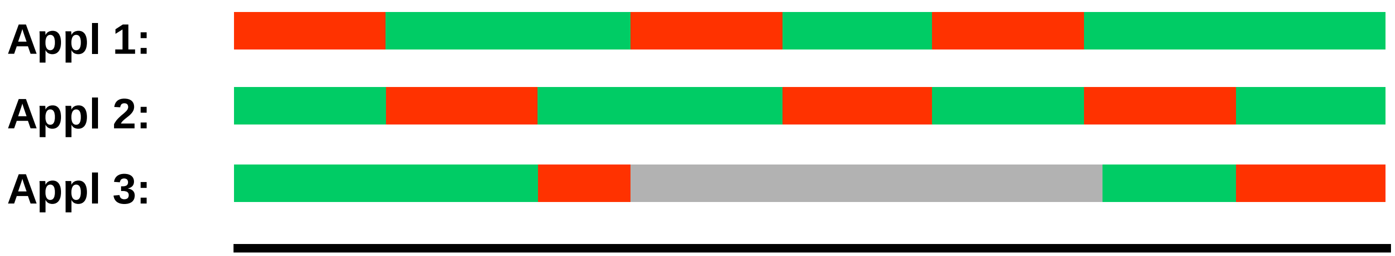
Multitasking allows several processes (applications or services) to run concurrently

- 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://wwwagss.informatik.uni-kl.de/Lehre/BS9900/

Example scheduling in Windows NT:

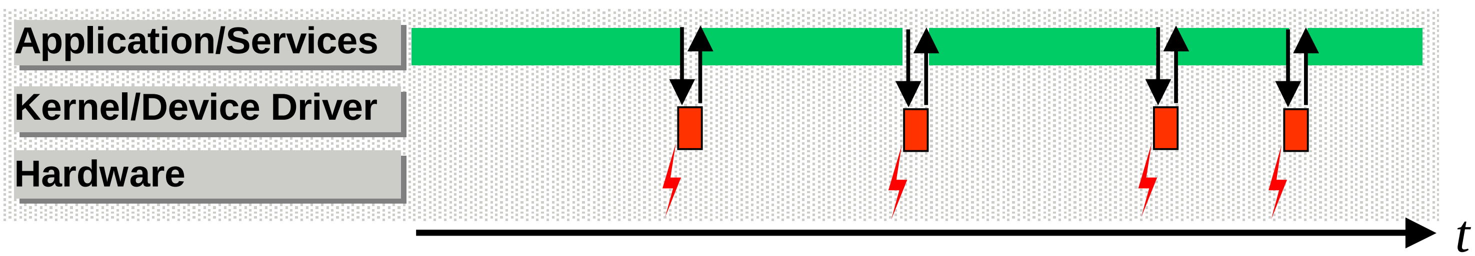
- Scheduling priorities depend on process + thread priorities
- Processes of the modes IDLE / NORMAL / HIGH are scheduled by a fair stratedy
  - Process priorities are raised and lowered dynamically to implement fairness
- REALTIME modes processes are assigned to the CPU in order of precedence
  - A 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 handeld by the kernel and device drivers:

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

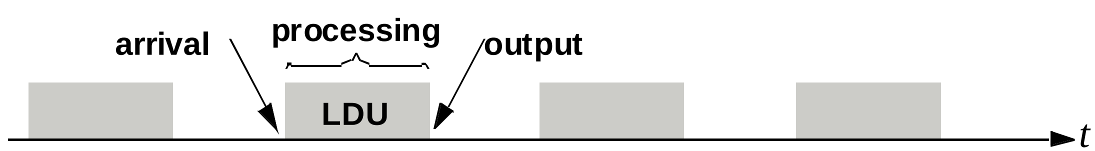


Problems of Continuous Media processing

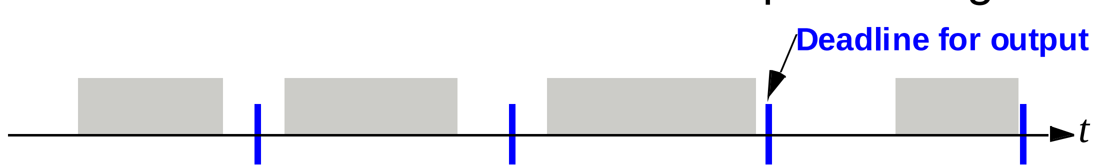
Irregular behavior of applications makes periodical processing of continuous media difficult, especially for real-time communication

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

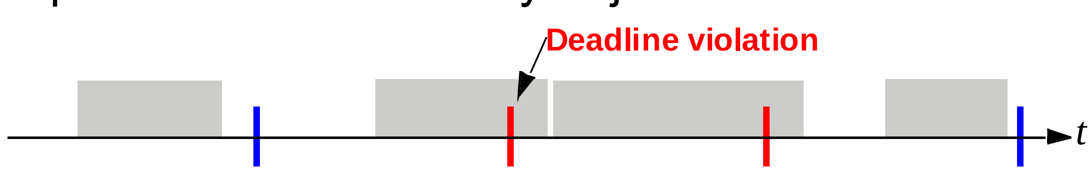
– Ideal: regular arrival and constant processing time, leads to regular output



– 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.

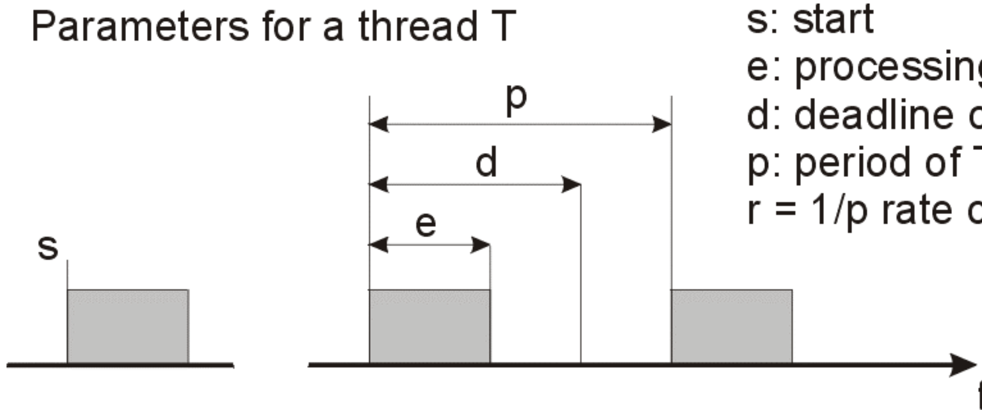
Properties of Real-Time systems:

- 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



s: start
e: processing time of T
d: deadline of T
p: period of T
r = 1/p rate of T

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 $\theta(n2)$
  - 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)

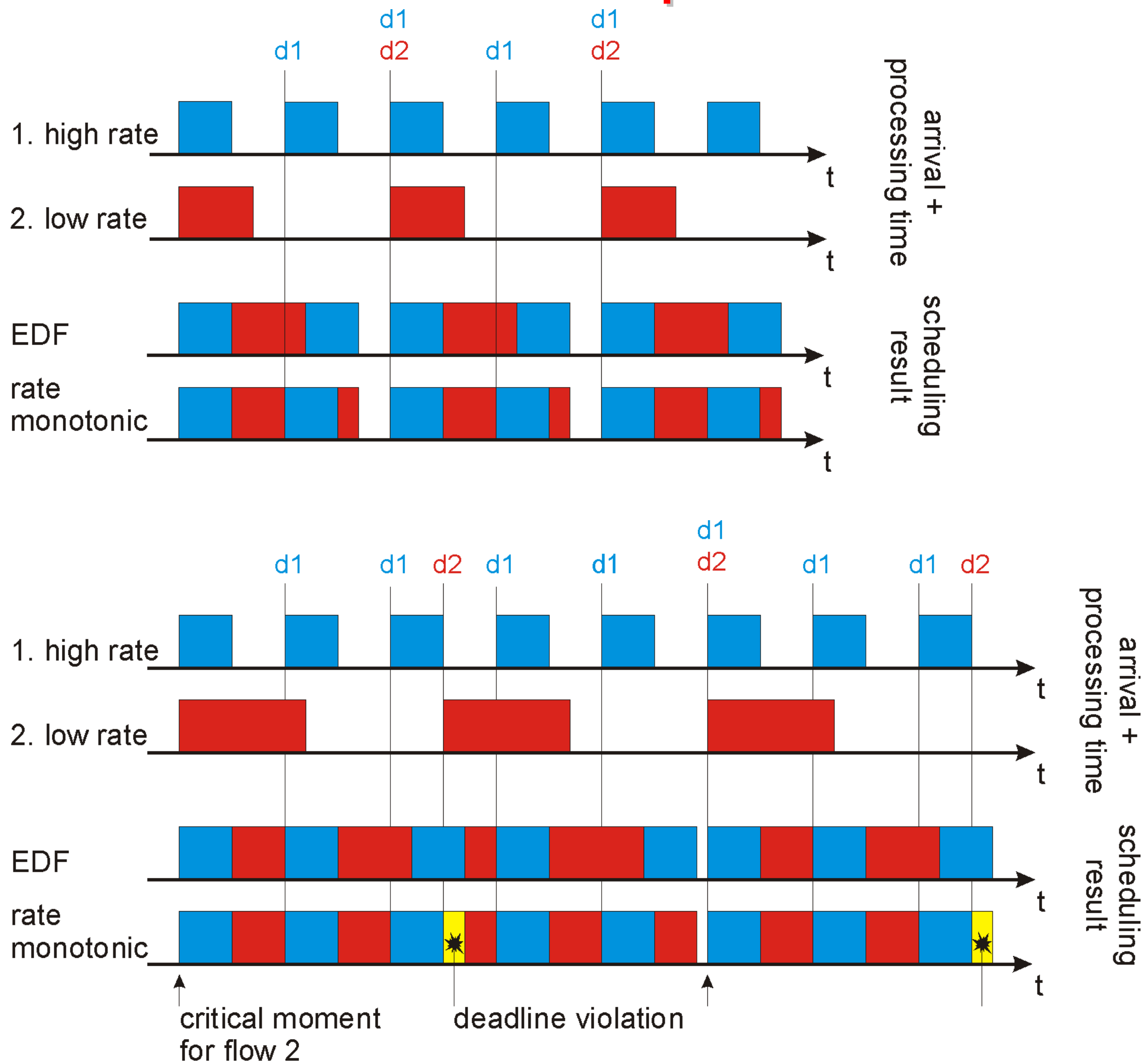
Another scheduling strategy

- 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 gauaranteed 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


d1
d1
d2
d1
d1
d2
1. high rate
2. low rate
EDF
rate
monotonic
t
arrival +
processing time
scheduling
result
d1
d1
d2
d1
d1
d1
d2
d1
d1
d2
critical moment
for flow 2
deadline violation

Scheduling Extensions

Support of non periodic processes

- Add virtual LDUs to create a periodic behaviour
  - Useful if a process is nearly periodic
  - Inefficient ressource 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
- Meassurement of thread parameters during run time
  - Requires a renew of the scheduling plan even for static strategies

Dispatcher (1)

...	...
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

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

Meta scheduler (priority scheduling)

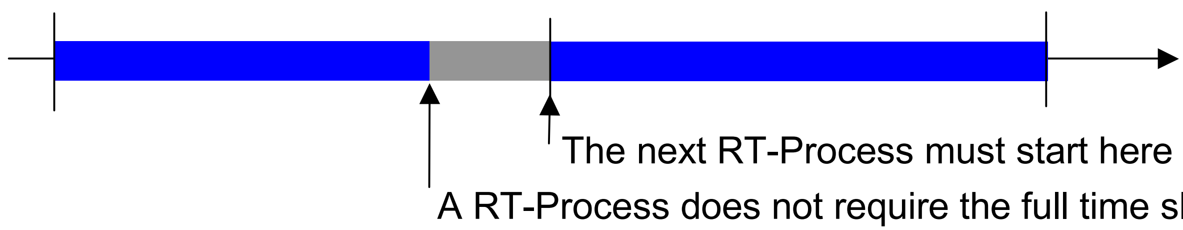
- Use the normal system scheduler and dispatcher
- Additionally use a meta scheduler to plan RT-Processes + wildcards for TS-Processes
- A meta dispatcher changes the priorities of the RT-Processes according to the meta scheduler
  - Starting a RT-Process: increase its priority to a high level
  - Starting 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 $t_n+\varepsilon$

- 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 effitiently



- 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.

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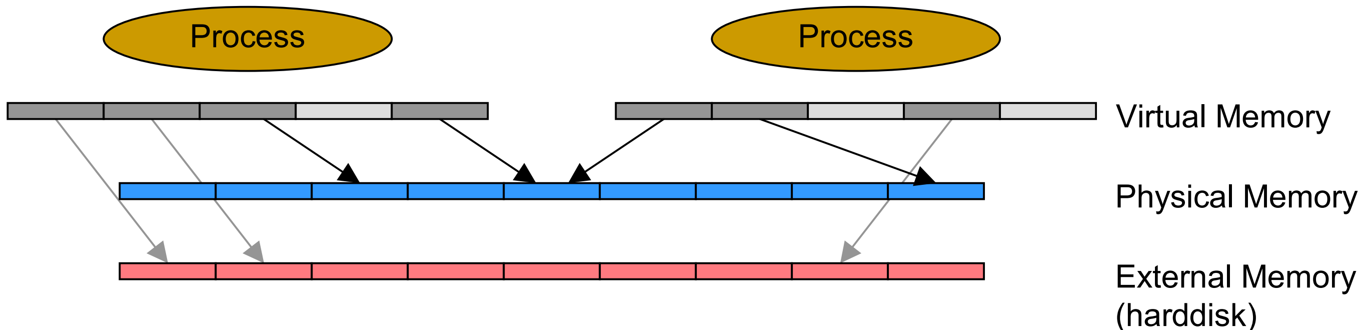
Managemet of Memory access

Memory management principle



- The whole memory is divided into pages
- Each process has its own virtual address space
- Virtual adresses are mapped to physical addresses by an Memory Management Unit (MMU)
- The physical memory is extended by external memory
  - Seldome 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

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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 to much pages are locked then the system performance is reduced significantly

Use shared memory to avoid copying of data

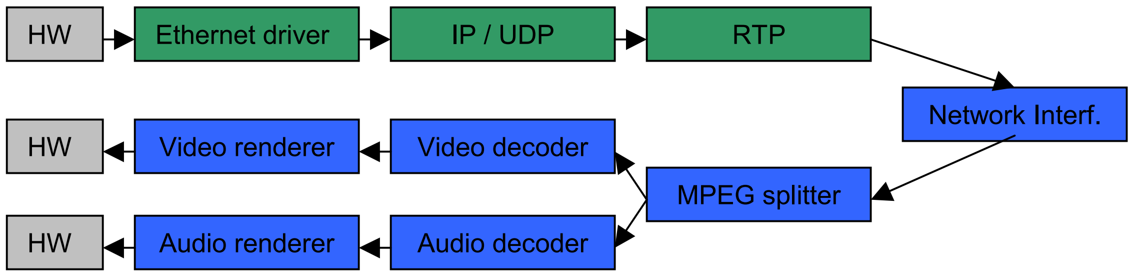
- Synchronization for memory access is required
- Use double buffering (or multiple buffers) for reader/writer relations in order to support parallel processing of different LDUs

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) unpredictible

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) suffcient 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 bottelneck

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 distributted over several harddisks using only one additional harddisk for a parity bit
- Since the harddisk controler is able to detect corrupted disks, the parity bit can replace any bit

Increasing Harddisk Throughput (2)

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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 distributted 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 bottelneck
- Like RAID-4 but the parity blocks are also distrubuted 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

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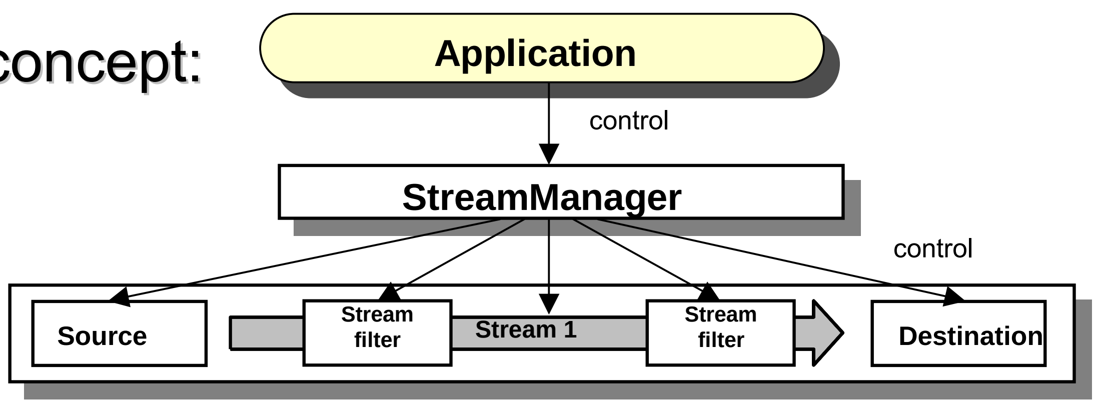
How to handle continuous media within applications?

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

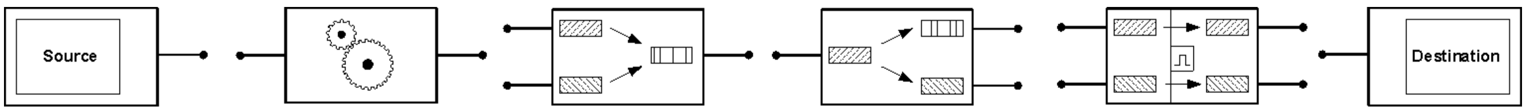
Stream concept:



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 reusage of software componets
- Easy handling for applications

Disadvantages

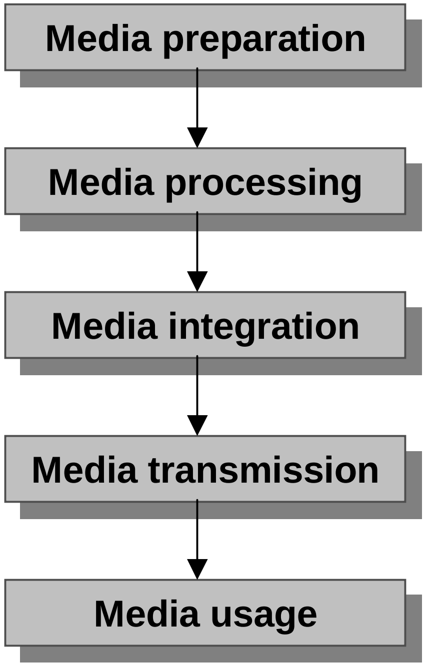
- If special data processing is required the application programmer must supply a new strem-filter

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
  - ...