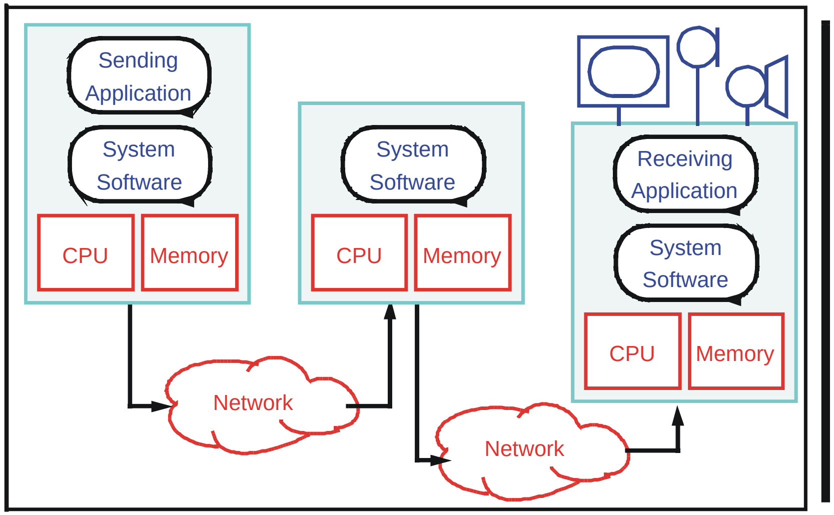
3. Quality of Service

3.1 Motivation

Kinds of systems we are dealing with are



Local
- Harddisk recording
- Interactive DVD
- Computer-based training

Distributed
- Conferencing
- Video on demand
- IP-Telephony

Basic terminology

- Resources
- Realtime
- Quality of Service

What and how much of it do we need, and how do we describe that?

Motivation for QoS

A QoS model and its implications

- QoS specification
- QoS calculation
- QoS enforcement

QoS has different implications in different fields:

- Operating system / Resource scheduling
- File system organization
- Compression
- Communication system support
- Media synchronization
- User Interface
- and more ...

3.2 Characteristics of Real-Time / Multimedia Systems

Real-time System:

"A system in which the correctness of a computation depends not only on obtaining the right result, but also upon providing the result on time."

Real-time Process:

"A process which delivers the results of the processing in a given time-span."

Real-time applications - examples

- **Control of temperature in a chemical plant**
  - -driven by interrupts from external devices
  - -these interrupts occur at irregular and unpredictable intervals
- **A flight simulator**
  - -execution at periodic intervals
  - -scheduled by a timer service which the application requests from the OS

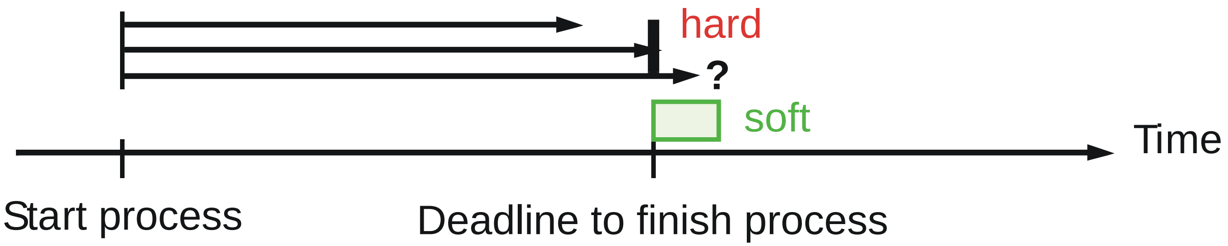
Common characteristics:

-internal and external events that occur periodically or spontaneous

-correctness also depends on meeting time constraints !

Deadlines in Realtime Systems

A deadline represents the latest acceptable time to finish an operation, e.g., for the presentation of a processing result



- **Hard deadlines:**
  - should never be violated
  - result presented too late (after deadline) has no value for the user
  - violation means severe (potentially catastrophic) system failure
  - Example: Nuclear power plant

- **Soft deadlines:**
  - deadlines are not missed by much
  - in some cases the deadline may be missed, but not too many deadlines are missed
  - presented result still has some value for the user
  - example: train/airplane arrival / departure

Realtime System - Requirements

Primary goal:

- deterministic behavior according to specification
- results in a variety of requirements

Mandatory requirements:

- Predictable (fast) handling of time-critical events
- Adequate schedulability
- Stability under overload conditions

Desirable requirements:

- Multi-tasking capabilities
- Short interrupt latency
- Fast context switching
- Control of memory management
- Proper scheduling
- Fine granularity of timer services
- Rich set of interprocess communication and synchronization mechanisms

Real-time in Multimedia Systems

A new application area for real-time systems with special characteristics:

- Typically soft real-time and not (that) critical
- Requirements may often be adapted to ensure proper handling, e.g., scaling of data streams to available bit rates

Characteristics

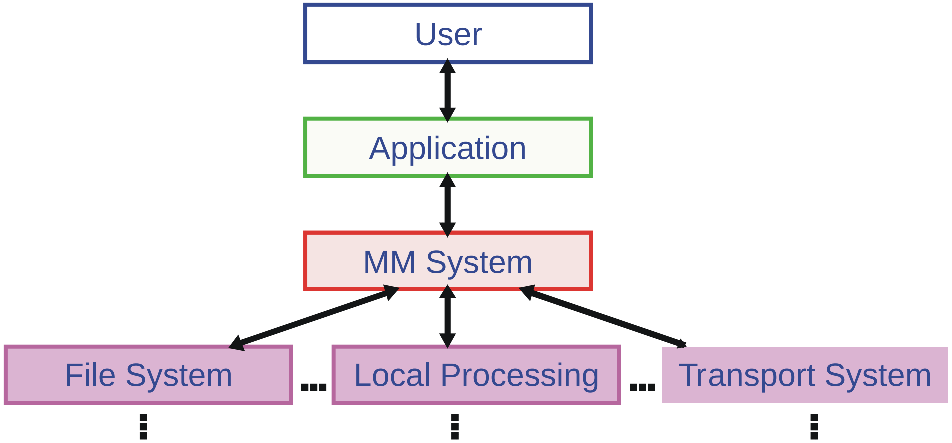
- Periodic processing
- Large bandwidth
- End-to-end guarantees
- Fault-tolerance
- Fairness
- Standardization

3.3 QoS - Definition

Quality of Service =

„well-defined and controllable behavior of a system according to quantitatively measurable parameters“

Layer model



Different service objects:

- Media / Streams
- Tasks
- Memory areas

QoS - Layer Model (1)

Examples: both qualitative / quantitative description

Perception QoS

- Tolerable Synchronisation Drift
- Visual Perceptability

Application QoS

- Media Parameters
- Media (Transmission) Characteristics

System QoS

- CPU Rate / Usage
- Available Memory

QoS - Layer Model (2)

Communication QoS

- Packet Size / Rate
- Bandwidth
- End-to-End Delay

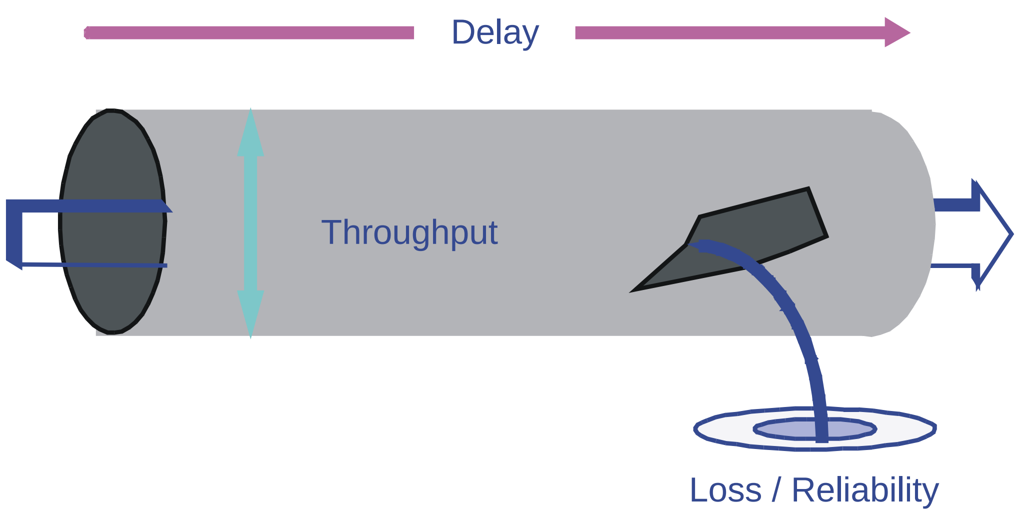
Device QoS

- Seek / data transfer rate of a disk
- Sampling rate / resolution of a camera

QoS Parameters – Example: Transport System

Common parameters concerning the Transport System are:

- Throughput
- Delay / Jitter
- Loss / Reliability



But also:

- Security
- Cost
- Stability (Resilience)

QoS Parameter Example

Delay

- Maximum end-to-end delay for transmission of one packet
- Delay jitter = variance of transmission times

Throughput

- Maximum long-term rate = maximum amount of data units transmitted per time interval (e.g. ,packets or bytes per second)
- Maximum burst size
- Maximum packet size

Loss

- Sensitivity class: ignore / indicate / correct losses
- Loss rate = maximum number of losses per time interval
- Loss size = maximum number of consecutively lost packets

Service Classes

Guaranteed Service

- values or intervals of QoS parameters
  - deterministic (at any time)
  - statistical (consider a time interval or a certain probability)

$$QoS_{min} \text{ <= } P \text{ <= } QoS_{max}$$

Predictable Service

- consider history
  - from the very beginning of calculation
  - in a shifting time window
- “if it was like that in the last ..., you can rely on ...”

Best-Effort Service

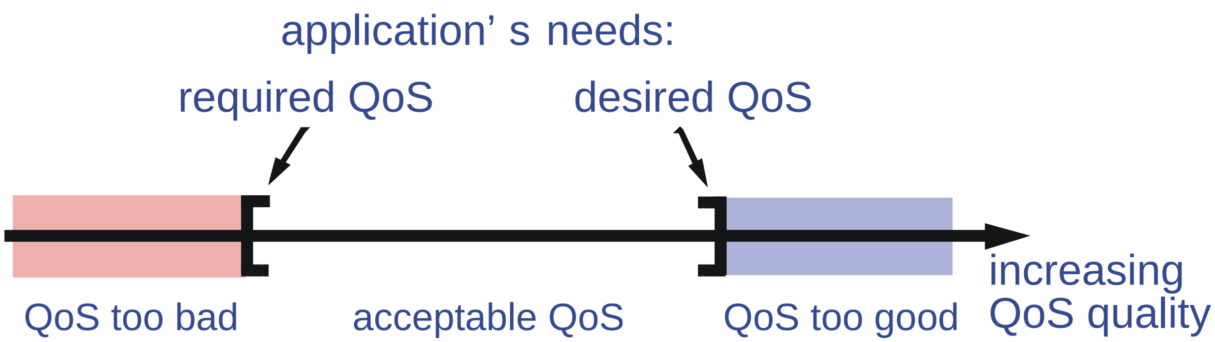
- no guarantees given

QoS Intervals (1)

Parameter values result in

- inacceptable regions
- acceptable regions

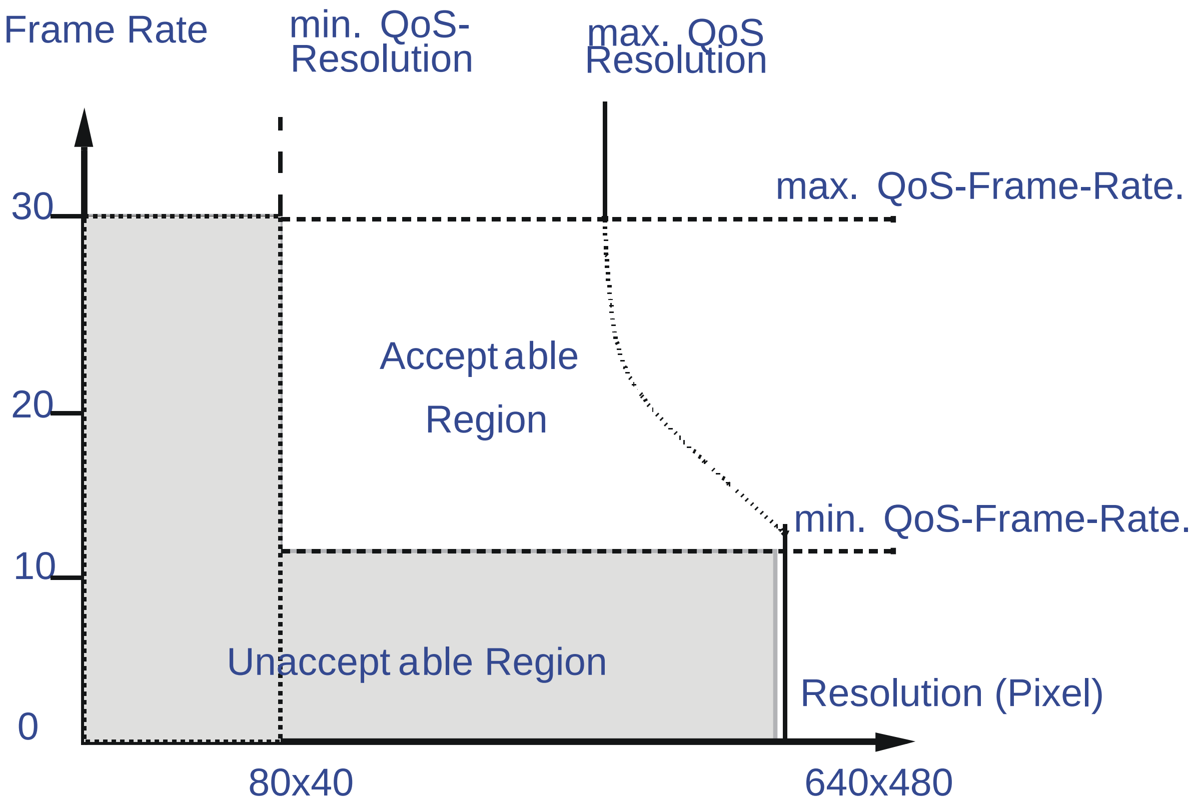
of QoS in one-dimensional intervals



- Below required QoS level - no useful service
- Above required QoS level - unnecessary (useless) resource consumption / cost

QoS Intervals (2)

Also: multidimensional intervals



3.4 Resources

Classification

By functionality

- active resources
  - actively fulfill a certain task
  - e.g., processor, network adapter
- passive resources
  - provide “space”
  - e.g., memory, frequency spectrum, file system

By availability for concurrent usage

- exclusive
- shared

By occurrence

- single
- multiple

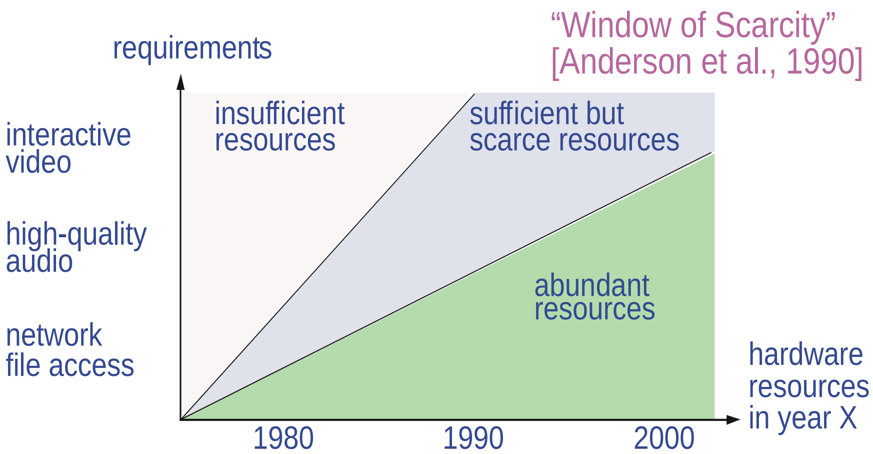
Common parameter:

- “Capacity“ - allows quantitative description

Resources - Availability

Starting point:

- scarce but sufficient resources



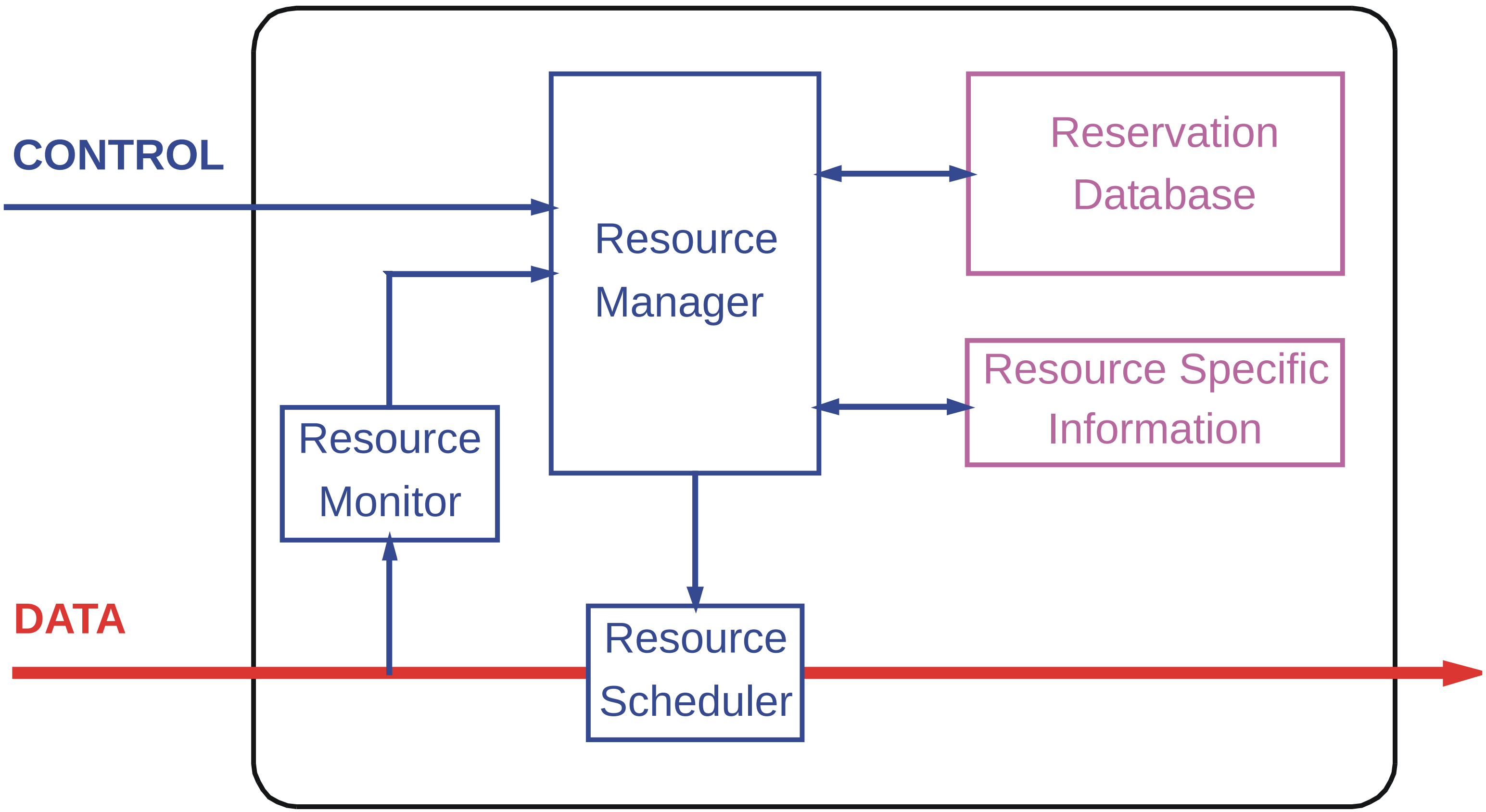
Goal

Provide best service at the lowest possible cost

Conclusion

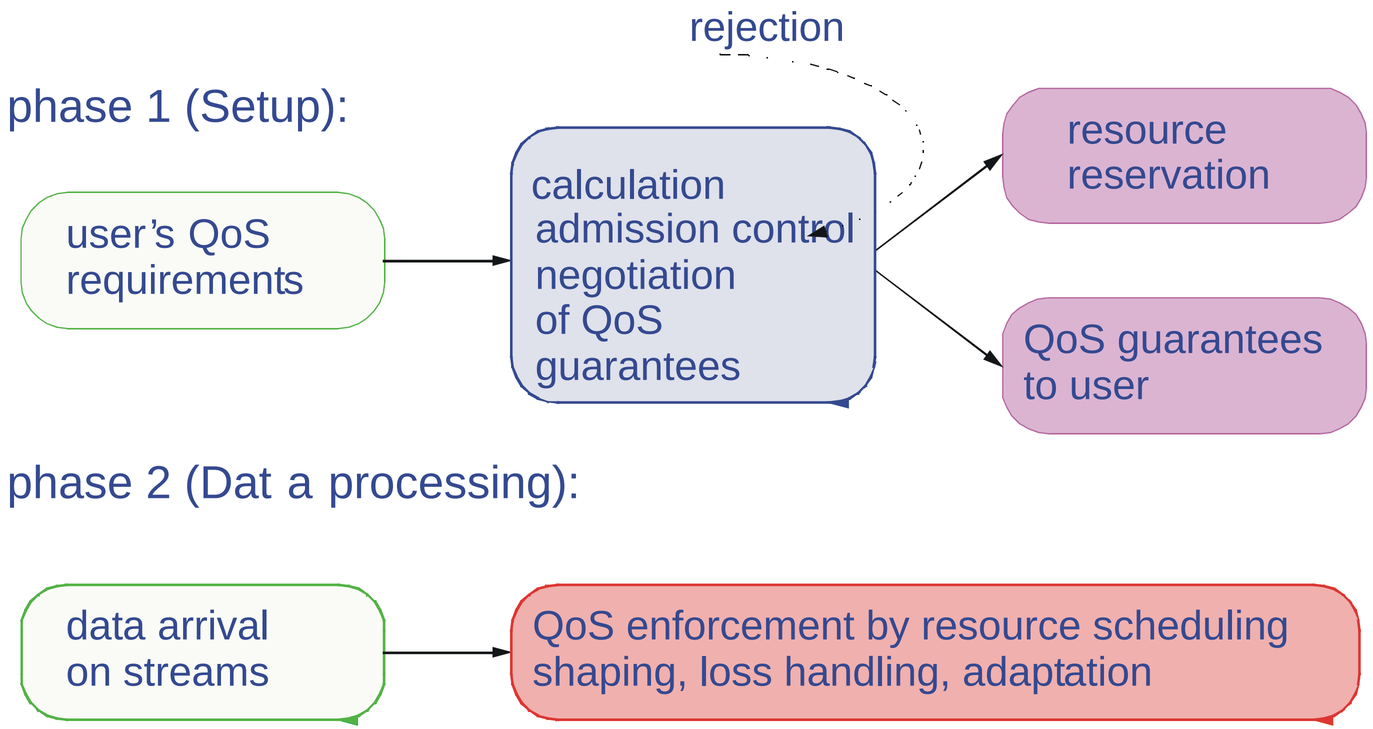
We need resource management in all components of a multimedia system

Architecture

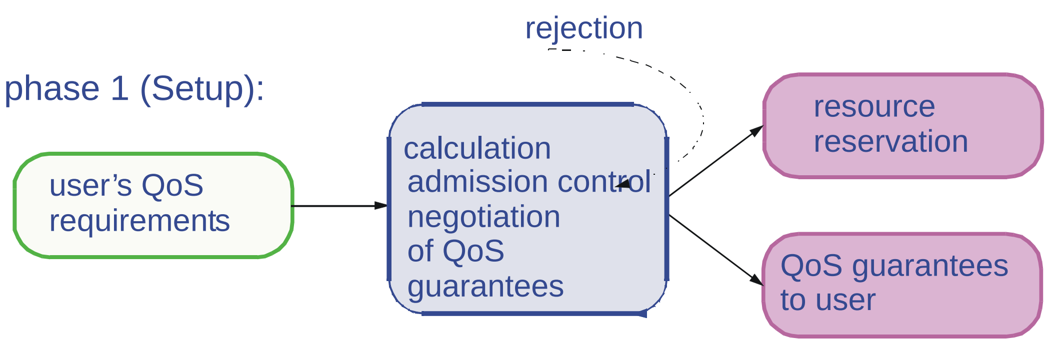


3.5 Providing QoS

Resource Management Phases



3.5.1 QoS Provisioning – Setup Phase



Definition of required parameters

- implicitly or explicitly by application or user

Distribution and negotiation

Translation between different layers

- especially if they use different semantics / notations

Transformation

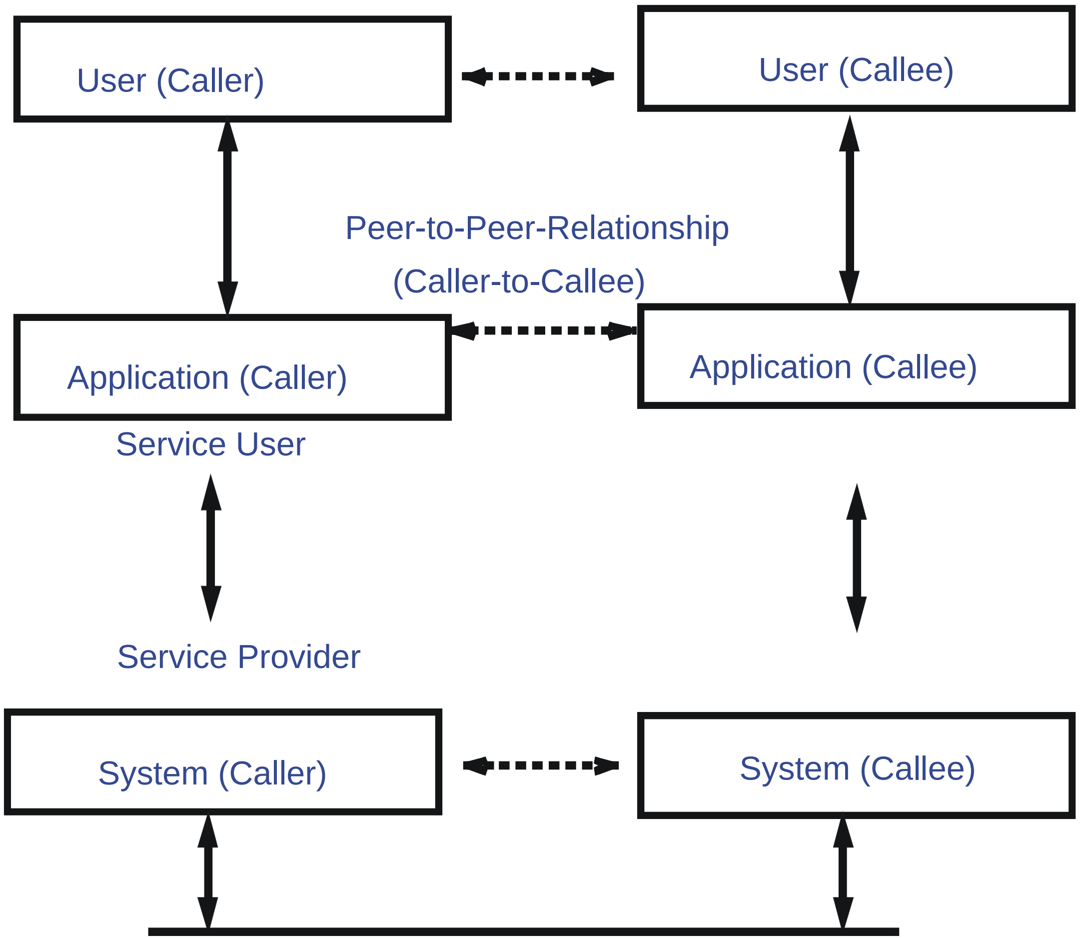
- QoS parameter => Resource requirements

Allocation and coordination of resources

- along path(s) from source(s) to sink(s)

QoS Calculation and Negotiation

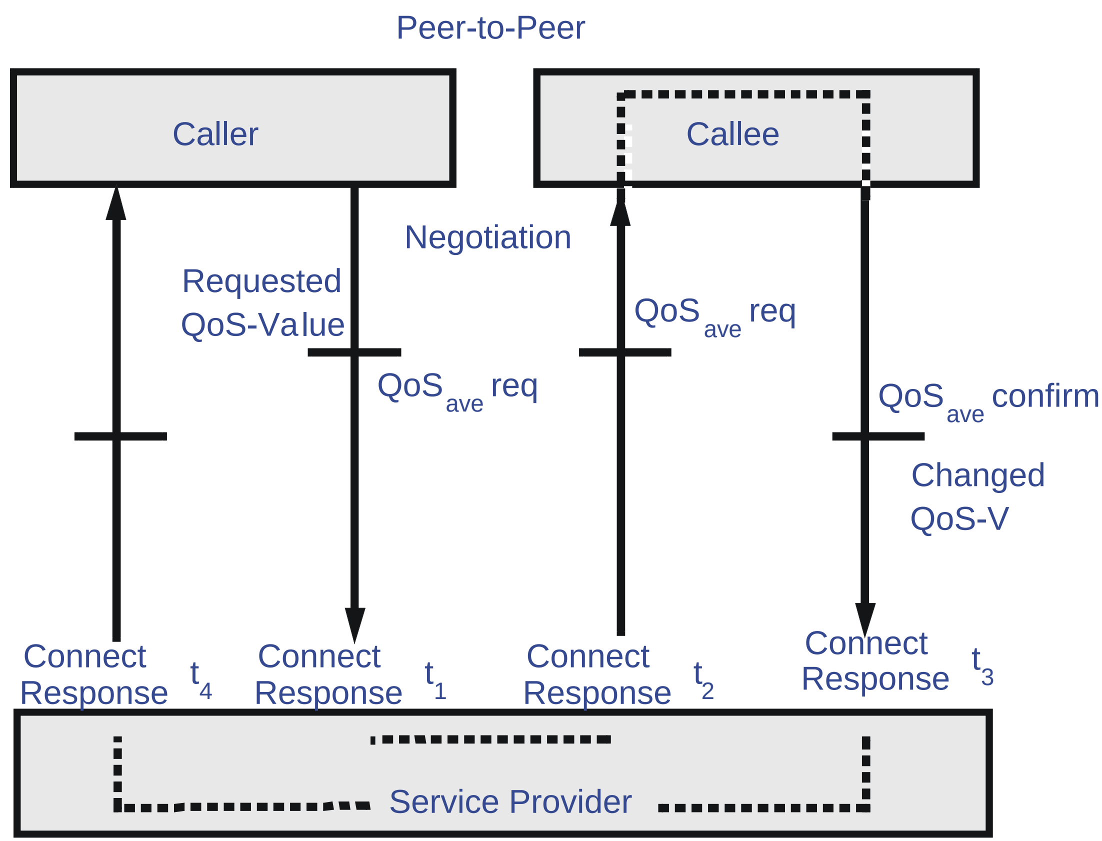
Model



QoS Negotiation (1)

Bilateral peer-to-peer

- service provider may not modify requested QoS parameters
- only the service user at the receiver side may modify (lower) the value(s) in the confir-mation message



QoS Negotiation (2)

Bilateral layer-to-layer

- **only between adjacent layers**
  - between local service users and providers
  - between sender and network

Unilateral

- **no modification of requested QoS parameters allowed, but just accept or reject**
- receiver may accept QoS parameter although he cannot meet them
  - example: color TV broadcast

Hybrid

- **uses unilateral mode for a certain bilateral layer-to-layer negotiation**
  - example: broadcast/multicast communication

    ===> heterogeneity of receivers

Further:

- **trilateral for information exchange**
- **trilateral for a limited target value**

Admission Control

The system checks whether requested resources are and will be available. Especially important for shared resources:

- CPU
- network paths
- buffer space.

A simple rule

Check whether the sum of the resources already in use and new request(s) is less or equal to the available resource capacity.

More specific: check for

- schedulability
- availability of buffers (space)
- bandwidth

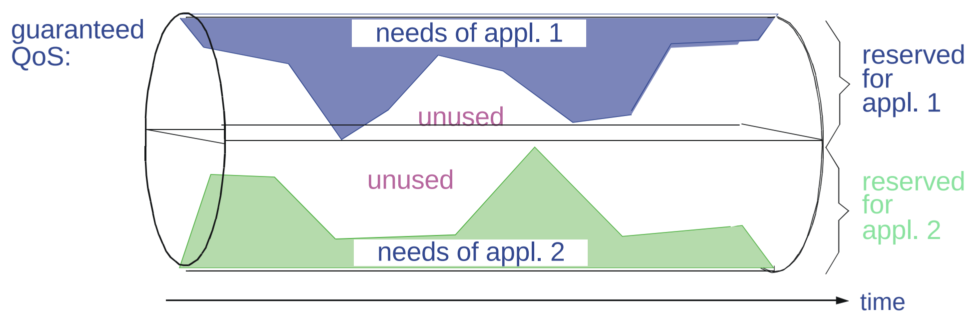
Note:

- strong relationship with *pricing / billing*
- efficient mechanisms will use “economic feedback” to prevent users from always requesting the maximum

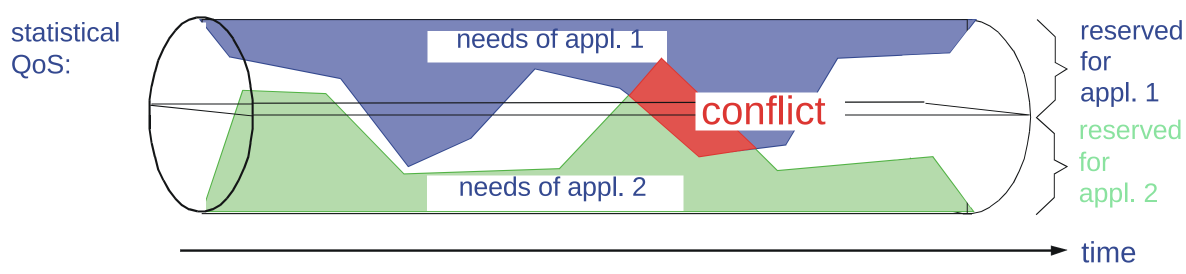
Resource Reservation

Fundamental concept for the reliable provision of QoS guarantees

- pessimistic - results in **Guaranteed QoS**



- optimistic - results in **Statistical QoS**



Resource Reservation Aspects - Example

Example: Communication System

Reservation Models

- Sender-initiated
- Receiver-initiated
- Explicit vs. implicit
- Out-of-Band vs. In-Band

Reservation Style

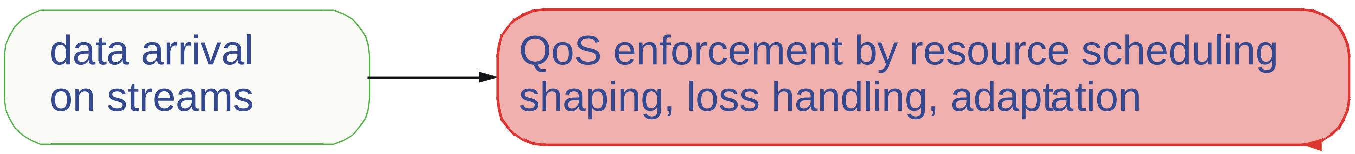
- Semantics and notation
- Heterogeneity and multicast support

Reservation Protocols

- ST-II for IP multicast
- RSVP (Resource reSerVation Protocol) for IP multicast

3.5.2 QoS Provisioning – Data Processing Phase

phase 2 (Dat a processing):



Maintain resource reservations

Use:

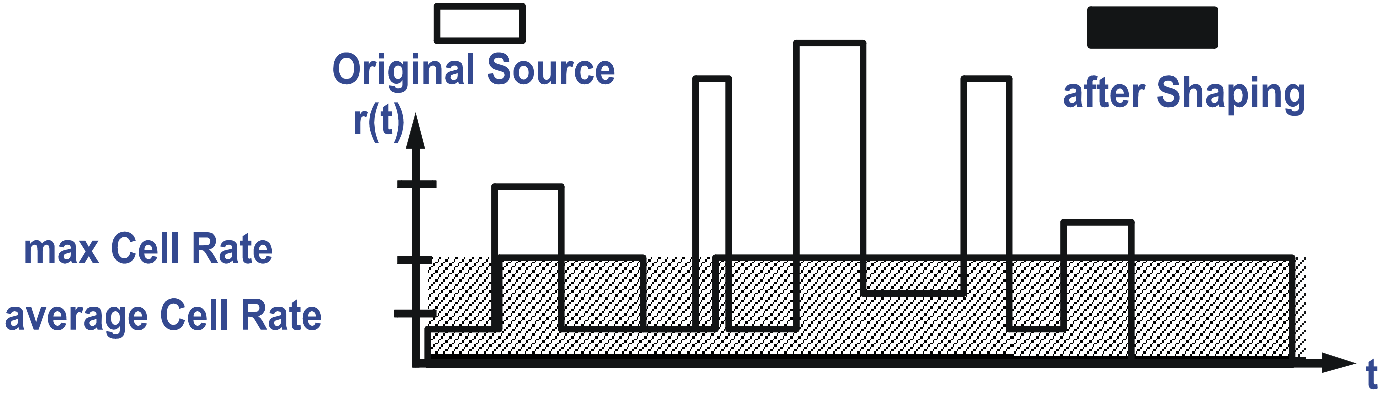
- adequate traffic shaping (to ensure characteristics of processed data)
- scheduling algorithms
- feedback and adaption of the streams

Shaping

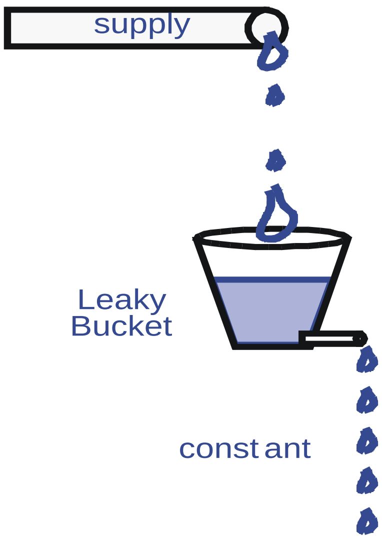
Characteristics of Multimedia Traffic:

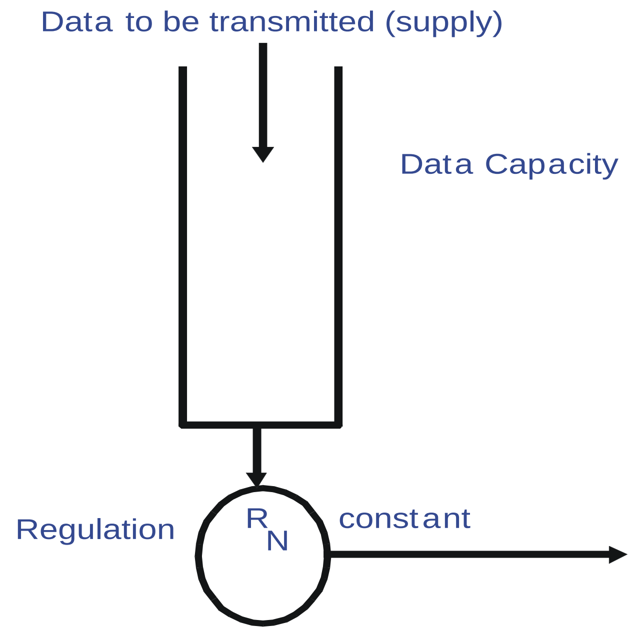
- bursty
- concurrent requests may cause problems though guarantees could be met (e.g., buffer overflow)

Basic principle



Shaping – Leaky Bucket Algorithm





Bucket Size

- determines maximum capacity till overflow (drop) and possible delay

Other Algorithms

- Token Bucket Algorithm
- Token Bucket Algorithm with Leaky Bucket Rate Control

Loss Handling

Error Detection

- **by means of redundancy / checks / analysis**

Loss handling algorithms fall into two basic categories:

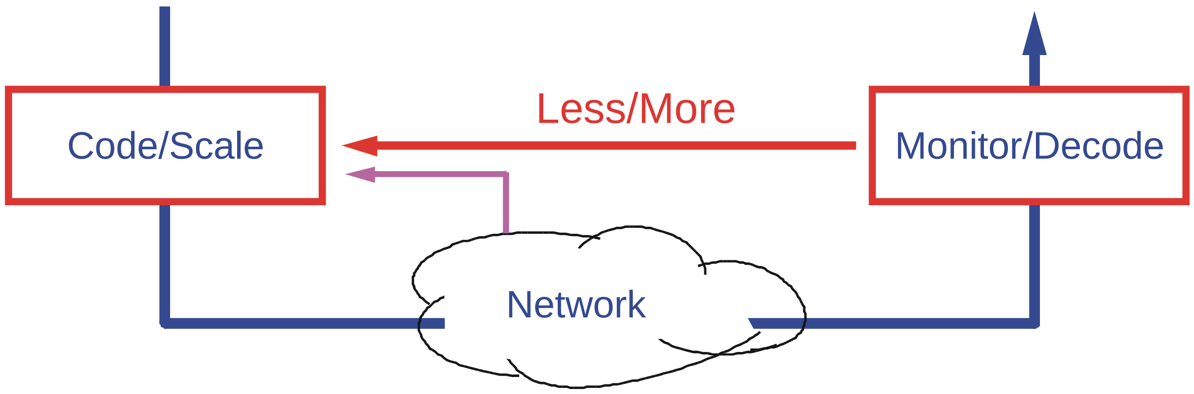
- **Retransmission**
  - Go-back-N retransmission
  - Selective retransmission
- **Prevention**
  - Forward Error Correction (FEC)
  - Priority Coding
  - Slack Automatic Repeat Request

Adaptation - Feedback Control

Monitor the load of network and local end-system resources

If significant changes occur, take appropriate action to reduce generated load:

- Explicit communication – receiver tells sender to slow down
- Completely within the network on a hop-by-hop basis
- By feedback from congested network nodes to the sender.



Variety of possible reactions

- e.g., layered transmission
- adaptive degradation of the stream quality
- ...

3.6 QoS Architectures

Examples (communication layer)

- **Integrated Services in the Internet**
  - uses existing infrastructure, but deploys dedicated handling of flows (streams) in the transfer system
  - Resource Reservation Protocol RSVP to support heterogenous needs
- **Differentiated Services in the Internet**
  - Granularity based on the ToS (Type of Service) IP Header Field
  - Define service classes, negotiate service level agreements and ensure dedicated treatment of flows that behave as described
- **IPv6**
  - QoS support was an important design criterion from the beginning
  - Dedicated header fields to allow classification / dedicated treatment of flows