4.2 Quality of Service in the
Network **4.2 Quality of Service in the Network**

in Networks **4.2.1 General Considerations forin Networks QoS**

A fundamental rule **A fundamental rule**

the network. Continuous media require Quality-of-Service support in the network. Continuous media require Quality-of-Service support in

Idea: Service Level Agreement **Idea: Service Level Agreement**

A contract between the application and the network. A contract between the application and the network.

- •promises to conform to that specification The promises to conform to that specification. **source** specifies the traffic it will generate and
- • The **network** promises the transmission of this traffic with guaranteedQoS.

QoS Parameters **QoS Parameters**

Traffic description of the source Traffic description of the source

Type of traffic: CBA, VBA, UDA, : Type of traffic: CBR, VBR, UBR, ...

•

- For constant traffic: bit rate For constant traffic: bit rate
- For bursty traffic: average bit rate, peak bit rate, duration of peaks duration of peaks traffic: average bit rate, peak bit rate,

QoS parameters of the network

- Delay
- Delay jitter (variance of the delay) Delay jitter (variance of the delay)
- Maximum loss rate Maximum loss rate

Real-World Examples Real-World Examples

Three examples: **Three examples: How resources in the network influence QoS.**

- will increase the end-to-end delay. video) allows to compensate more delay jitter, but it will increase the end-to-end delay. video) allows to compensate more delay jitter, but it A large playoutbuffer at the receiver (e.g., for
- With increasing load of a router the average waiting existing connections can still be maintained accepted when delay guarantees given to the connections through that router should only be time of packets in the queues will increase. New (Connection Acceptance Control). existing connections can still be maintained accepted when delay guarantees given to the connections through that router should only be time of packets in the queues will increase. New With increasing load of a router the average waiting (Connection Acceptance Control).
- The CPU power of a router determines the per time interval maximum number of packets that can be handled per time interval. The CPU power of a router determines the maximum number of packets that can be handled

The QoS Mapping Problem

How is QoS mapped from level to level?

Example

A QoS Mapping Example

Deterministic QoS Guarantees

will be guaranteed at all times (The QoS negotiated between application and network **hard QoS bounds**).

QoS calculation is based on:

- Hard bounds of the traffic generated by the source Hard bounds of the traffic generated by the source
- · Worst-case assumptions concerning concurrent streams and available network resources Worst-case assumptions concerning concurrent streams and available network resources

Advantage **Advantage**

• the worst load conditions the worst load conditions QoS guarantees will always be fulfilled, even under

Disadvantages Disadvantages

- No statistical multiplexing gain tor VBR traffic No statistical multiplexing gain for VBR traffic
- More frequent rejection of new connections More frequent rejection of new connections

are often not required (unlike for the control of real-time conterence. processes). Example: video quality in a video For multimedia applications deterministic guarantees conference. processes). Example: video quality in a video are often not required (unlike for the control of real-time For multimedia applications deterministic guarantees

Probabilistic QoS Guarantees

QoS values have **soft bounds**

.

QoS calculation is based on:

- A stochastic description of the traffic load A stochastic description of the traffic load
- A probabilistic specification of the behavior of the network (" in 95% of all cases the delay will be < A probabilistic specification of the behavior of the $\frac{1}{10}$ in 95% of all cases the delay will be \leq 100 ms ")

Advantages **Advantages**

- Statistical multiplexing gain Statistical multiplexing gain
- More parallel connections can be permitted More parallel connections can be permitted

Disadvantages Disadvantages

- O
So will not be optimal at all times
- Quite difficult to implement Quite difficult to implement

QoS Definition: The ATM Example

defines precisely what traffic types a source can send: The standard for ATM (Asynchronous Transfer Mode) defines precisely what traffic types a source can send: The standard for ATM (Asynchrous Transfer Mode)

• CBR, ABR, ABR, DBR **CBR, VBR, ABR, UBR**

parameters that characterize VBR traffic: The ATM standard also defines precisely the parameters that characterize VBR traffic: The ATM standard also defines precisely the

• **size average cell rate, peak cell rate, maximum peak**

(see ITU-T standard Q.93b) (see ITU-T standard Q.93b)

QoS and Reservation QoS and Reservation

in the network! **in the network! No QoS guarantee without reservation of resources**

- We need local resource management within the network nodes (inner nodes and end nodes). We need local resource management within the network nodes (inner nodes and end nodes).
- We need reservation protocols We need reservation protocols.
- We need a surveillance of the sources ("source specifications. policing") to ensure that they conform to their traffic specifications. policing") to ensure that they conform to their traffic We need a surveillance of the sources ("source

A Protocol For Resource Reservation A Protocol For Resource Reservation

The Principle **The Principle**

- Connection-oriented communication Connection-oriented communication
- Reserve all the resources you can get on the path from the source to the destination from the source to the destination Reserve all the resources you can get on the path
- over resources. When arriving at the destination, compute the leftover resources. When arriving at the destination, compute the left-
- Relax the left-over resources on the way back, redistributing them, with the confirmation message distributing them, with the confirmation message Relax the left-over resources on the way back, re-

Protocol Flow (1) Protocol Flow (1)

Protocol Flow (2)

Protocol Flow (2)

∑

<u>م.</u> =

Left over:

80 ms

60 ms

Reserve Request

Reserve Request

QoS requested by the application: ${\mathsf D}_{\mathsf{max}}$ = 140 ms

d maxR1

d
maxR2

= 65 ms

= 50 ms

Reserve Confirm

Reserve Confirm

Relaxation strategy: equally over all routers

Relaxation strategy: equally over all routers

$$
d_{T1} = 5 \text{ ms}
$$

\n
$$
d_{T2} = 15 \text{ ms}
$$

\n
$$
d_{T3} = 5 \text{ ms}
$$

\n
$$
d_{T1} = 10 \text{ ms}
$$

$$
l_{R1} = 10 \text{ ms}
$$

$$
Q_{R2} = 25 \text{ ms}
$$

$$
Q_{R2} = 25 \text{ ms}
$$

$$
x_1 = 10 \text{ m/s}
$$

$$
m = 10 \, \text{m}
$$

$$
= 52 \text{ m/s}
$$

$$
z = 25 \text{ m}
$$

$$
= 25 \text{ ms}
$$

Multimedia Technology A Graduate Course

Communication \odot Molfgang Effelsberg, $\qquad \qquad 4.2\cdot$ 11 $\qquad \qquad 4.2\cdot$ 11

4. Multimedia
Communication

 $4.2 - 11$

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Communication

 $4.2 - 12$

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$$
\begin{array}{c}\n1 \\
1 \\
2 \\
3\n\end{array}
$$

$$
\begin{array}{c}\n\vdots \\
\vdots \\
\vdots \\
\vdots\n\end{array}
$$

$$
\begin{array}{c}\n\mathbf{i} \\
\mathbf{m}\n\end{array}
$$

$$
\frac{1}{2}
$$

$$
\begin{array}{c}\n1 \\
1 \\
2 \\
3 \\
3\n\end{array}
$$

$$
\begin{array}{c}\n1 \\
1 \\
2 \\
3 \\
1 \\
1\n\end{array}
$$

$$
\begin{array}{c}\n1 \\
1 \\
2 \\
3 \\
1\n\end{array}
$$

$$
= 10
$$

$$
= 25
$$

$$
= 10
$$

$$
\begin{array}{c}\n1 & 0 \\
1 & 0 \\
1 & 0\n\end{array}
$$

$$
= 100
$$

$$
= 10 \text{ ms}
$$

$$
10\,\mathrm{ms}
$$

$$
\begin{array}{c}\n 10 \text{ m/s} \\
 25 \text{ m/s}\n \end{array}
$$

4.2.2 QoS4.2.2 QoS in the Internet **in the Internet**

Curent Internet: Best Effort model Current Internet: Best Effort model

in the case of overload serviced by the routers on a FIFO basis with "Tail-Drop" this model, all packets are treated equally. Packets are The current Internet is built on the Best Effort model. In serviced by the routers on a FIFO basis with this model, all packets are treated equally. Packets are The current Internet is built on the Best Effort model. In in the case of overload. "Tail-Drop"

The advantage of this model is that it is simple enough to run The advantage of this model is that it is simple enough at very high speeds.

New Applications Require QoS

applications, in particular audio and video and other suffice any more to satisfy the requirements of new The problem of the Best Effort model is that it does not real-time applications, such as games real-time applications, such as games. applications, in particular audio and video and other suffice any more to satisfy the requirements of new The proplem of the Beat measure is that it does not

Differentiated Services architecture (DiffServ). **Differentiated Services architecture (DiffServ).** Currently the most popularဝ
တ technology for IP is the

application. each class in a differentiated manner according to its application. ဝ
၁
၁ each class in a according toWith needs. Assignment of the class is done by the DiffServ, traffic is separated into QoS **differentiated** requirements.manner according to its DiffServ**classes** then treats

Two Traffic Classes: ElasticTwo Traffic Classes: Elastic and Real**and Real-Time**

two classes: According to the DiffServ model, trafficAccording to the DiffServ model, traffic is classified into is classified into **elastic traffic** and **real-time** traffic.

- Examples of elastic traffic are file transfer, electronic tolerant of delays. mail and remote terminal access. Elastic traffic is tolerant of delays. mail and remote terminal access.Examples of elastic traffic are file transfer, electronic Elastic traffic is
- Examples of real-time traffic are audio and video. Real-time traffic is very sensitive to delay. Real-time traffic is very sensitive to delay. Examples of real-time traffic are audio and video.

Elastic Traffic Elastic Traffic

increases. rate of performance enhancement as bandwidth the bandwidth. It experiences a diminishing marginal the bandwidth.The performance of elastic traffic depends mainly on The performance of elastic traffic depends mainly on increases. rate of performance enhancement as bandwidth It experiences a diminishing marginal

Real-Time Traffic Real-Time Traffic

delay bound. Data has no value if it arrives later than this bound. Real-time traffic needs its data to arrive within a given this bound. delay bound. Data has no value if it arrives later than Real-time traffic needs its data to arrive within a given

Goals of DiffServ

elastic and real-time traffic as they are identified by their utility functions. their utility functions. elastic and real-time traffic as they are identified by DiffServ should satisfy the different requirements of

due to their complexity. mechanisms so that it scales well and can be deployed due to their complexity. easily. Some previous proposals formechanisms so that it scales well and can be deployed DiffServ aims at providingဝ
တ with simple QoS have failed

The fundamental DiffServ principle

possible. Keep processing in the core routers as simple as to the end systems or edge routers of sub-networks). to the end systems or edge routers of sub-networks). Push the complexity to the "edges" of the network (i.e. Keep processing in the core routers as simple as Push the complexity to the "edges" of the network (i.e.,

Pushing the Complexity to the Edge Pushing the Complexity to the Edge (1)

Edge (end system) **Edge (end system)**

- Keeps per-flow state Keeps per-flow state
- Marks the packets according to: Marks the packets according to:
- Sending rate of the user Sending rate of the user
- Contract between the user and the network (Service Level Agreement, SLA) (Service Level Agreement, SLA) Contract between the user and the network
- The result of this marking is inserted into a label in the IP packet header. **The result of this marking is inserted into a label in the IP packet header.**

Core (router) **Core (router)**

- Gives a differentiated treatment to each packet according to its label, in particular a different priority in the packet queue of the router according to its label, in particular a different priority Gives a differentiated treatment to each packet in the packet queue of the router
- Does not keep per-flow state **Does not keep per-flow state**

Pushing the Complexity to the Edge Pushing the Complexity to the Edge (2)

Two-Bit Differentiated Services Two-Bit Differentiated Services Architecture Architecture

current proposes three different The so-called "Two-Bit Architectrue" is the passis of the levels of service: current proposal in the IETF. It proposes three different The so-called "Two-Bit Architecture" is the basis of the levels of service:

- Premium Service **Premium Service**
- · Assured Service **Assured Service**
- · Best Effort Service **Best Effort Service**

Packets get differentiated by two bits in their header: Packets get differentiated by two bits in their header:

- Premicm bit (P-bit is on) Premium bit (P-bit is on)
- Assured Service bit (A-bit is on) Assured Service bit (A-bit is on)

Premium Service Premium Service

its packets. Therefore it is suited for real-time traffic. Premium Service provides very low delay and jitter to its packets.**Premium Service** Therefore it is suited provides very low delay and jitter to **for real-time traffic**

conterence over the Internet. to pay a premium price to run a high-quality video A typical user of this service could be a company willing to pay a premium price to run a high-quality video A typical user of this service could be a company willing conference over the Internet.

Premium Service: End System Action Premium Service: End System Action

of the packets on if the sender is in conformance to the
SLA. The Premium traffic is shaped/smoothed to network. prevent traffic bursts from being injected into the **Marking:** The end system or edge router turns the P-bit SLA. The Premium traffic is shaped/smoothed to of the packets on if the sender is in conformance to the prevent traffic bursts from being injected into the The end system or edge router turns the P-bit

Premium Service: Core Router Action Premium Service: Core Router Action

other packets later. Forwarding: Core routers send Premium packets first, other packets later. **Forwarding:** Core routers send Premium packets first,

Assured Service Assured Service

suited for elastic traffic that requires some performance guarantees but it assures a committed bandwidth. Therefore, it is Assured Service does not provide delay guarantees, **Assured Service** performance guarantees. but it assures a committed bandwidth.**for elastic traffic** does not provide delay guarantees, that requires some Therefore, it is

its Web site. make its service reliable and give its users a fast feel of business on the Web willing to pay a certain price to A typical user of this service could be a company doing A typical user of this service could be a company doing its Web site. make its service reliable and give its users a fast feel of business on the Web willing to pay a certain price to

Best Effort Service **Best Effort Service**

or bandwidth guarantees. It is meant to be used for Best Effort Service does not provide any kind of delay **non-QoS**or bandwidth guarantees. It is meant to be used Best Effort Service **traffic**. does not provide any kind of delay

performance. traffic there is the danger of experiencing a null traffic there is the danger of experiencing a null It should be used for elastic traffic only; with real-time performance. It should be used for elastic traffic only; with real-time

4.2-26

Assured and Best Effort Services: End Assured and Best Effort Services: End Systems

otherwise capacity profile, and are classified out-of-profile with the Assured Service and stays within the expected belong to a user that has contracted a specific capacity otherwise. capacity profile, and are classified with the Assured Service and stays within the expected belong to a user that has contracted a specific capacity **Marking:** Packets are classified **in-profile out-of-profile** if they

Assured and Best Effort Services: Assured and Best Effort Services: Core Routers Core Routers

congest the network. control is such that in-profile packets alone do not congestion leads to dropping the out-of-profile packets are put into the same queue: the low-priority queue. dropped. This will be true as long as the admission first, while in-profile packets are very unlikely to be The low-priority queue is managed in such a way that Forwarding: All packets, in-profile and out-of-profile congest the network. control is such that in-profile packets alone do not dropped. This will be true as long as the admission first, while in-profile packets are very unlikely to be congestion leads to dropping the out-of-profile packets The low-priority queue is managed in such a way that are put into the same queue: the low-priority queue. **Forwarding:** All packets, in-profile and out-of-profile,

Admission Control Admission Control

that: Admission Control is necessary in order to guarantee **Admission Control** is necessary in order to guarantee

- Premium Service traffic is limited to some small amount (say, 20 %) of the bandwidth of input links amount (say, 20 %) of the bandwidth of input links. Premium Service traffic is limited to some small
- In-profile packets of Assured Service alone do not congest the network. congest the network. In-profile packets of Assured Service alone do not

This is performed with the Bandwidth Broker (BB): This is performed with the Bandwidth Broker (BB):

- The BB keeps track of all Premium/Assured Service contracted in the network. contracted in the network. The BB keeps track of all Premium/Assured Service
- Based on this information it decides whether new requests can be granted requests can be granted. Based on this information it decides whether new

the Internet is still a research issue Design and implementation of bandwidth brokers for the Internet is still a research issue. Design and implementation of bandwidth brokers for

- Edge routers keep per-flow state for the flows traversing them (a small number) traversing them (a small number). Edge routers keep per-flow state for the flows
- Core routers do not need to keep per-flow state Core routers do not need to keep per-flow state.
- systems is an application matter. H
Mo to assign marks to IP packets in the end

bandwidth broker which is not yet well defined The main difficulty with the deployment of the IETF's bandwidth broker which is not yet well defined. DiffServ The main difficulty with the deployment of the IETF's is admission control to be provided by a

