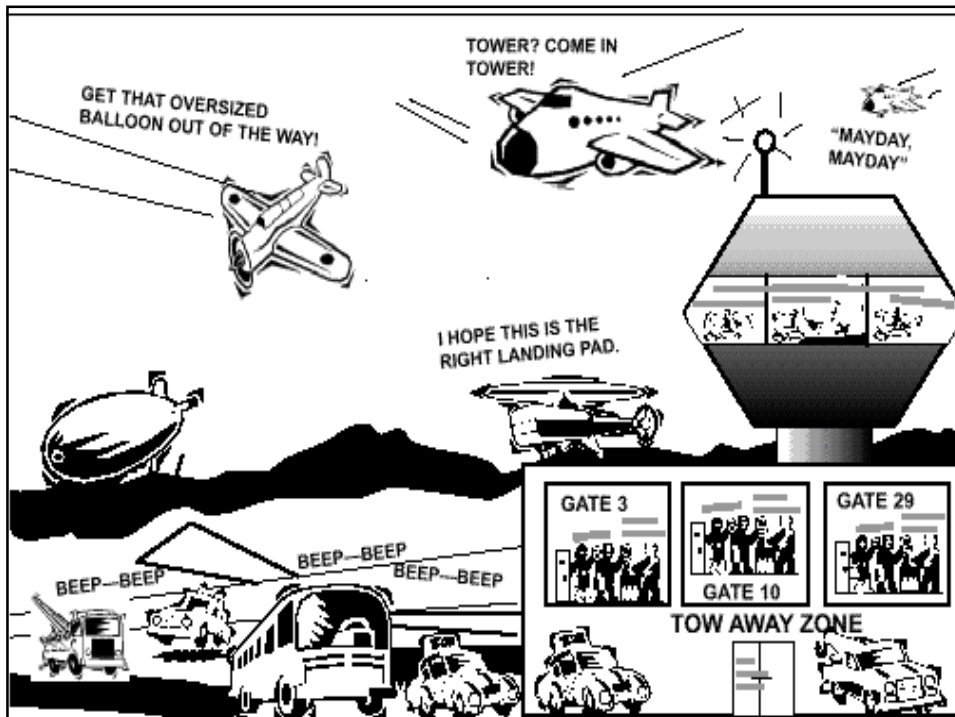


## Decus Bonn 7.-11. April 2003

Einführung in Quality of Service



Eva Heinold  
CCCSC München  
eva.heinold@hp.com






## Agenda

- What is QoS?
- Factors, influencing Quality of each Application**
- Packetloss, Delay, Delay-variations
- QoS Demands for**
- Voice, Video, Data
- QoS Tools**
- Classification
  - Marking
  - Trust Boundaries
- Scheduling
- Provisioning
  - Congestion avoidance, Policing, Shaping
- Management
- QoS Design Considerations**

## What is Quality of Service?



“

**The Pragmatic Answer:**  
QoS is Advanced Resource Management

**The Technical Answer: The Resources!!**

Set of techniques to manage:

- Delay
- Delay Variation (Jitter)
- Packet Loss
- Bandwidth

”

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But...but... Bandwidth.....



“

**“Money and sex, storage and bandwidth:  
only too much is ever enough”**

- Arno Penzias - Former Head of Bell Labs, and Nobel prizewinner

”

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QoS is Fundamental to Voice/Video (and Data)



**Applications**

- Standards-based
- Personalized

**Voice and Video Telephony**

- Scalable
- Flexible


**Network Infrastructure**

- **QoS-Enabled**
- Resilient
- Security


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## Factors that Affect the Quality of Any Application




IP Telephony




Oracle 11i




Microsoft EDC



SAP 4.6



HP UDC




Video Conferencing

**Delay**  
(Latency)

**Delay-Variation**  
(Jitter)


**Packet Loss**

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- **QoS Design Considerations**

## QoS Requirements for Voice



### Voice



- Smooth
- Easy to Provision
- Drop Sensitive
- Delay Sensitive
- UDP Priority


- Latency  $\leq 150$  ms
- Jitter  $\leq 30$  ms
- Loss  $\leq 1\%$

- 17-106 kbps guaranteed priority bandwidth per call
- 150 bps (+ layer 2 overhead) guaranteed bandwidth for Voice-Control traffic per call

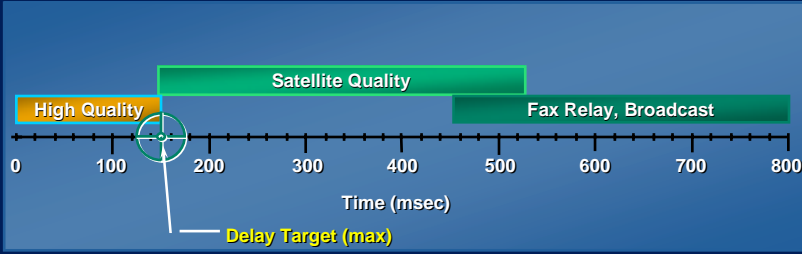
One-way requirements

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## VoIP Delay Budget




### Cumulative Transmission Path Delay





**ITU's G.114 Recommendation = 0–150 msec 1-Way Delay**

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## QoS Requirements for Video-Conferencing



### Video

- Bursty
- Greedy
- Drop Sensitive
- Delay Sensitive
- UDP Priority


- Latency  $\leq 150$  ms
- Jitter  $\leq 30$  ms
- Loss  $\leq 1\%$

} One-way requirements



- Minimum bandwidth guarantee required is:  
Video-Stream + 20%
  - e.g. for a 384 kbps stream a reserved 460 kbps of priority bandwidth is recommended

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## QoS Requirements for Data



### Data

- Different applications have different traffic characteristics
- Different *versions* of the same application can have different traffic characteristics
- Classify Data into relative-priority model with a maximum of four classes

**Gold: Mission-Critical Apps (ERP Apps, Transactions)**

**Silver: Guaranteed-Bandwidth (Intranet, Messaging)**

**Bronze: Best-Effort (Email, Internet)**

**Less-Than-Best-Effort: Scavenger (FTP, Backups, Napster/Kazaa)**

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## Different Classification



Equant does classify as follows:

**Real Time Class** -- optimized for toll quality Voice over IP and time-sensitive applications.

**Interactive Class** -- designed to give quick response for business critical applications.

**Standard Business Class** -- suitable for day-to-day business applications, client server traffic and corporate web traffic.

**General Class** -- ideal for email, Internet http traffic and Notes replication.

For further information..<http://www.equant.com>

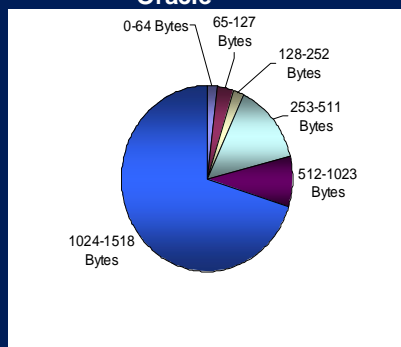
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## Provisioning for Data: Application Differences

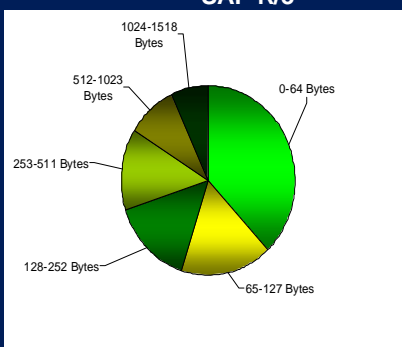


### Oracle



**Almost 75% of Oracle packets are greater than 1024 Bytes**

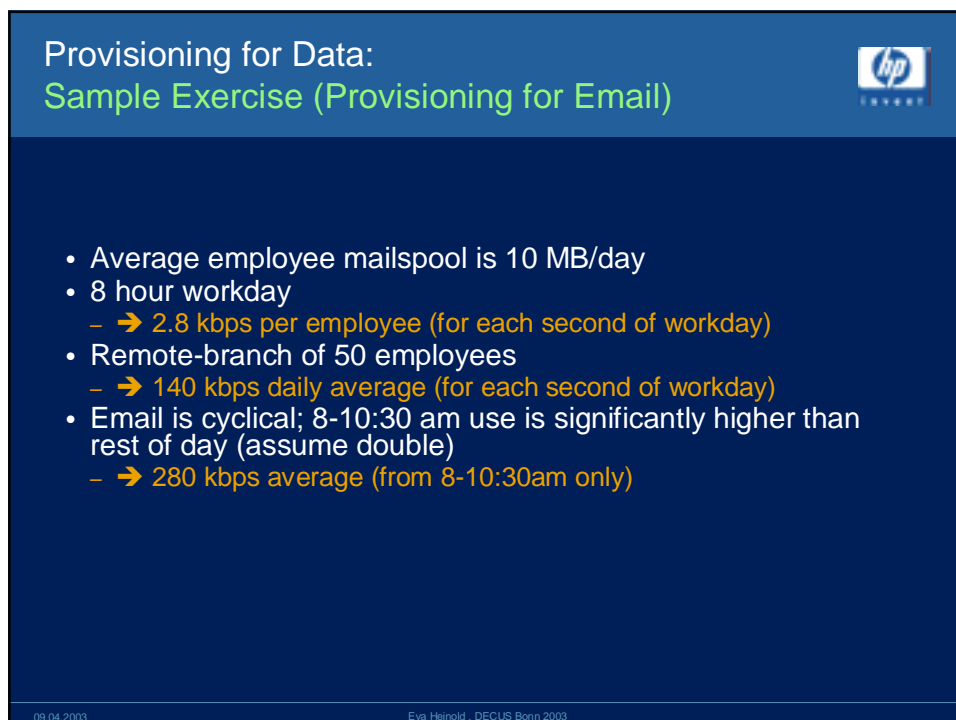
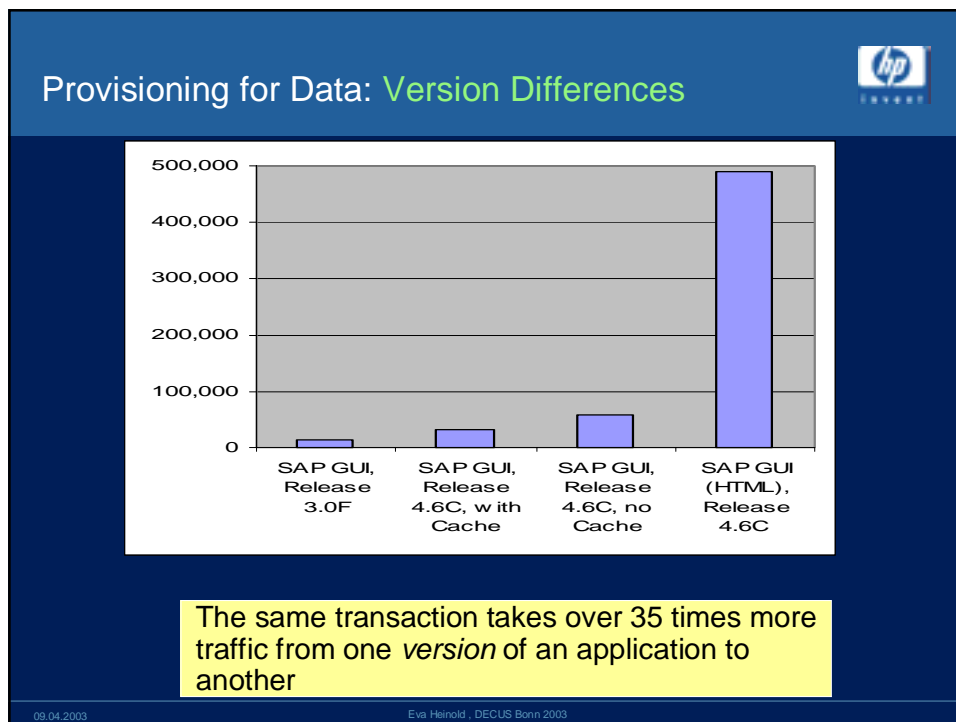
### SAP R/3



**Over 50% of SAP R/3 packets are less than 128 Bytes**

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## TCP Flow Statistics

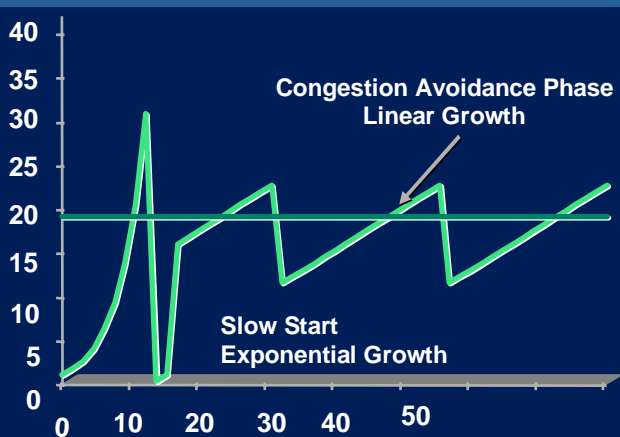


- >90% of sessions have ten packets each way or less
  - Transaction mode (mail, small web page)
- >10% of all TCP sessions produce 80% of the traffic
  - with high rate bursts
  - It is these that we worry about managing

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## Behavior of a High-Throughput / Bulk-Transfer TCP Session




- TCP will keep at most a certain amount of traffic in flight
  - We say it is "elastic"—rate is proportional to latency
- Voice will send only and exactly as fast as the coding algorithm permits (Also Video to an extent)
  - We say it is "inelastic"

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## Application QoS Requirements

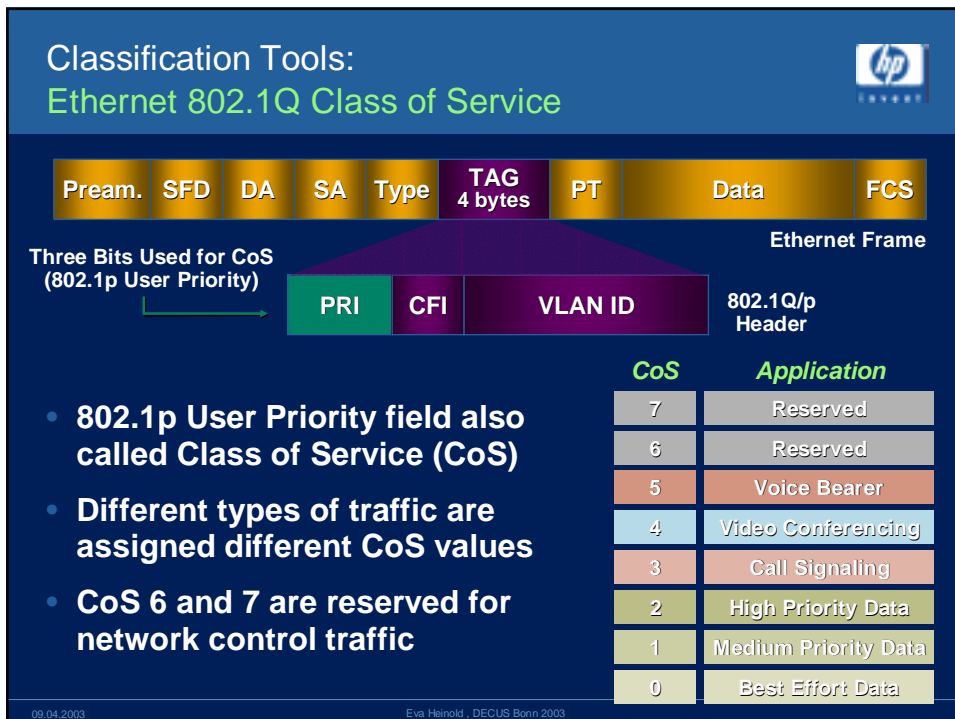
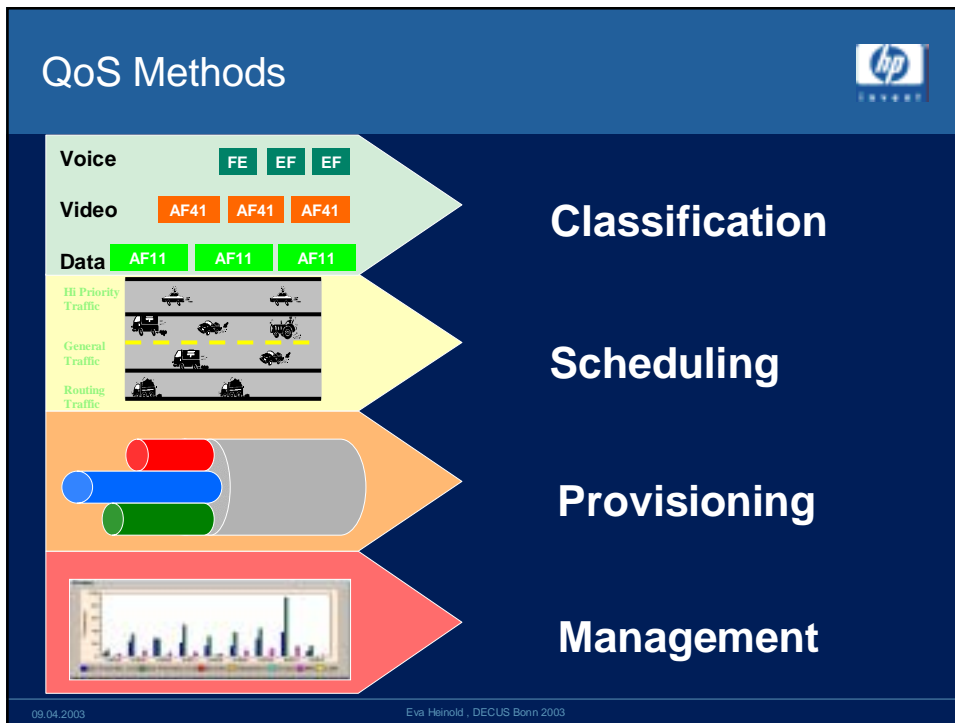


|                              | Voice           | FTP              | ERP and Mission-Critical |
|------------------------------|-----------------|------------------|--------------------------|
| <b>Bandwidth</b>             | Low to Moderate | Moderate to High | Low                      |
| <b>Random Drop Sensitive</b> | Low             | High             | Moderate To High         |
| <b>Delay Sensitive</b>       | High            | Low              | Low to Moderate          |
| <b>Jitter Sensitive</b>      | High            | Low              | Moderate                 |

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- QoS Tools**
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- **Marking**
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- Management
- QoS Design Considerations**



### Classification Tools: IPv4 IP Precedence and DiffServ Code Points

The diagram shows an IPv4 packet header with fields: Version Length, ToS Byte, Len, ID, Offset, TTL, Proto, FCS, IP SA, IP DA, and Data. The ToS Byte is further detailed as follows:

|               |   |   |        |   |      |   |           |
|---------------|---|---|--------|---|------|---|-----------|
| 7             | 6 | 5 | 4      | 3 | 2    | 1 | 0         |
| IP Precedence |   |   | Unused |   | DSCP |   | Flow Ctrl |

Standard IPv4 uses bits 7-5 (IP Precedence). DiffServ Extensions use bits 7-0 (DSCP and Flow Ctrl).


- **IPv4:** Three Most Significant Bits of ToS byte are called IP Precedence (IPP)—other bits unused
- **DiffServ:** Six Most Significant Bits of ToS byte are called DiffServ Code Point (DSCP)—remaining two bits used for flow control
- DSCP is backward-compatible with IP Precedence
- Layer 3 Mechanisms Provide End-to-End Classification

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### QoS Classification Summary


| Application                | L3 Classification |      |          | L2  |
|----------------------------|-------------------|------|----------|-----|
|                            | IPP               | PHB  | DSCP     | CoS |
| Reserved                   | 7                 | -    | 56-63    | 7   |
| Reserved                   | 6                 | -    | 48-55    | 6   |
| Voice Bearer               | 5                 | EF   | 46       | 5   |
| Video Conferencing         | 4                 | AF41 | 34       | 4   |
| Call Signaling             | 3                 | AF31 | 26       | 3   |
| High Priority Data         | 2                 | AF2y | 18,20,22 | 2   |
| Medium Priority Data       | 1                 | AF1y | 10,14,16 | 1   |
| Best Effort Data           | 0                 | BE   | 0        | 0   |
| Less-than-Best-Effort Data | 0                 | -    | 2,4,6    | 0   |

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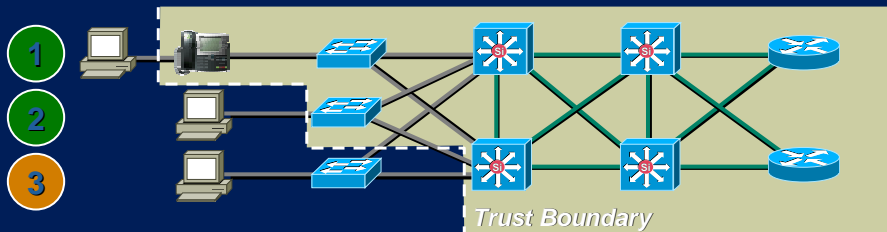


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## Classification Tools: Trust Boundaries




Endpoints      Access      Distribution      Core      WAN Agg.



- A device can be trusted if it correctly classifies packets
- For scalability, classification should be done as close to the edge as possible
- The outermost trusted devices represent the trust boundary
- 1 and 2 are optimal,
- 3 is acceptable (if access switch cannot perform classification)

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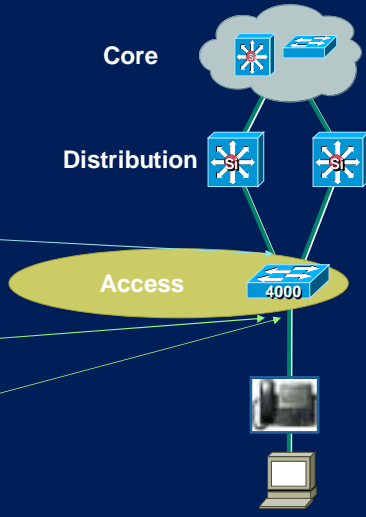
## Catalyst 4000 (SUP3) Example Access Layer—Access Port and Uplink



```

qos map cos 1 to dscp 10
qos map cos 2 to dscp 18
qos map cos 3 to dscp 26
qos map cos 4 to dscp 34
qos map cos 5 to dscp 46
!
qos
!
interface GigabitEthernet1/1
description Uplink to Distribution
qos trust dscp
no snmp trap link-status
tx-queue 3
priority high
!
interface FastEthernet4/1
description To IP Phone
qos trust cos
no snmp trap link-status
switchport voice vlan 111
switchport vlan 11
switchport priority extend cos 0
tx-queue 3
priority high

```




**Core**

**Distribution**

**Access**

4000

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## Catalyst 4000 (SUP3) Example Access Layer—Classification

```

qos map cos 1 to dscp 10
qos map cos 2 to dscp 18
qos map cos 3 to dscp 26
qos map cos 4 to dscp 34
qos map cos 5 to dscp 46
!
qos
!
class-map match-all VoIP-Bearer
 match access-group name VoIP-Bearer
class-map match-all Mission-Critical
 match access-group name Mission-Critical
class-map match-all VoIP-Control
 match access-group name VoIP-Control
!
policy-map VoIP-Policy
 class Mission-Critical
  set ip dscp 18
 class VoIP-Control
  set ip dscp 26
 class VoIP-Bearer
  set ip dscp 46
!
interface FastEthernet4/1
 qos trust cos
 service-policy in VoIP-Policy
 tx-queue 3
 priority high
        
```

**Core**

**Distribution**

**Access**  
Catalyst 4000

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## Scheduling Tools: Queuing Algorithms

```

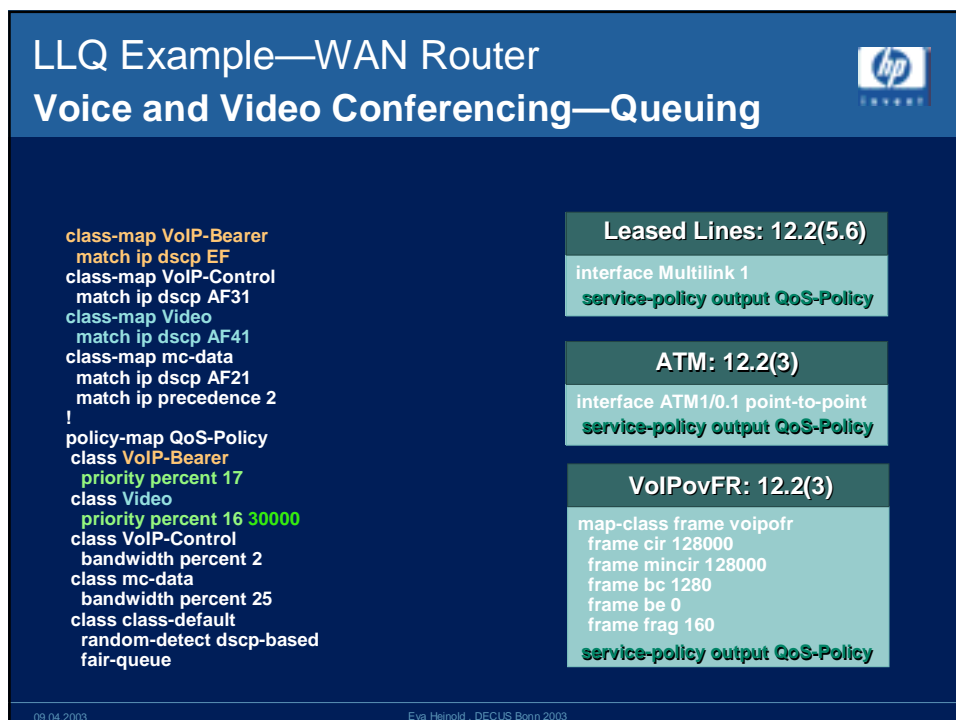
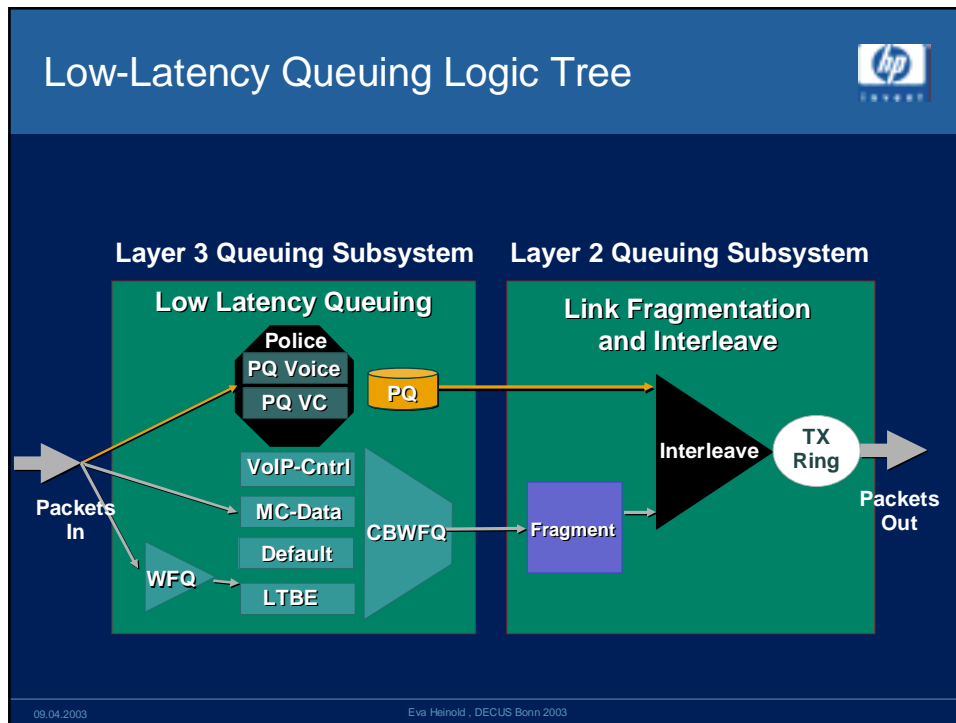
Voice   EF EF EF
Video  AF41 AF41 AF41
Data   AF11 AF11 AF11
        
```

**10/100m Ethernet**    **Queued**    **128k PVC**

Branch Router    WAN    WAN Aggregation Router

- Congestion can occur at any point in the network where there are speed mismatches
- Low-Latency Queuing (LLQ) used for highest-priority traffic (voice/video)
- Class-Based Weighted-Fair Queuing (CBWFQ) used for guaranteeing bandwidth to data applications

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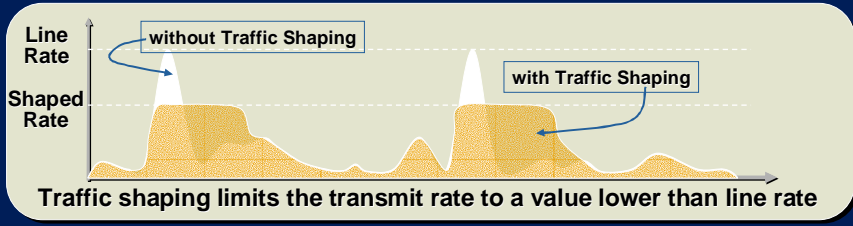




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## Provisioning Tools: Policers and Shapers



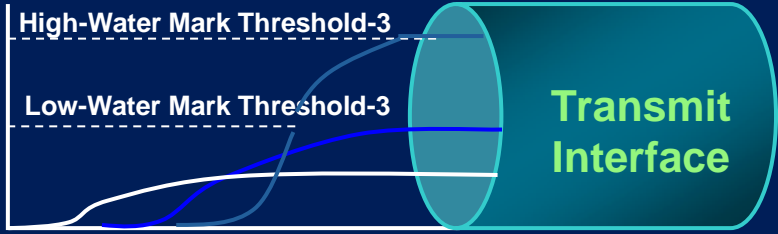


Traffic shaping limits the transmit rate to a value lower than line rate

- policers typically drop traffic
- shapers typically delay excess traffic, smoothing bursts and preventing unnecessary drops
- very common on Non-Broadcast Multiple-Access (NBMA) network topologies such as Frame-Relay and ATM

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## Scheduling Tools: Congestion Avoidance Algorithms



The diagram shows a queue represented as a cylinder. Two horizontal dashed lines indicate the High-Water Mark Threshold-3 (top) and Low-Water Mark Threshold-3 (bottom). A blue line representing the queue level rises from the bottom, crosses the Low-Water Mark, and then crosses the High-Water Mark. A red line represents the transmit interface, which is shown as a cylinder to the right of the queue. The queue level is shown to be below the High-Water Mark threshold.

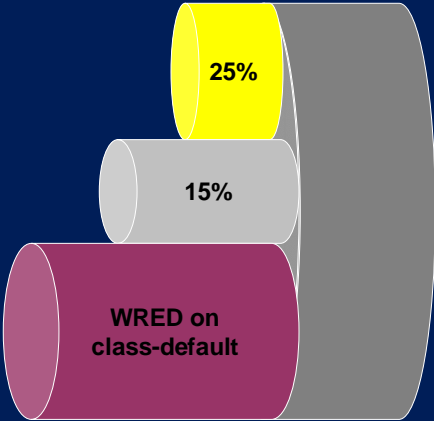
- Scheduling/Queuing algorithms manage the front of the queue
  - i.e. which packets get transmitted first
- Congestion Avoidance algorithms, like Weighted-Random Early-Detect (WRED), manage the tail of the queue
  - i.e. which packets get dropped first when queueing buffers fill
- WRED can operate in a DiffServ compliant mode which will drop packets according to their DSCP markings

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## WAN Classification and Provisioning Four Classes of Data into Three Queues

```

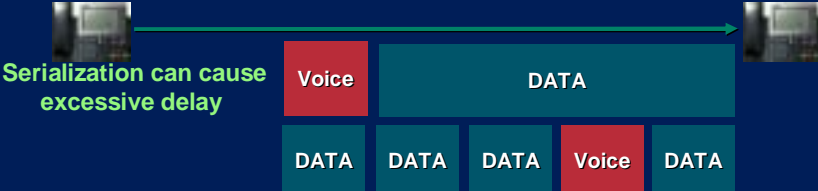
ip cef      (distributed)
!
class-map match-any GOLD-DATA
  match ip dscp af21
  match ip dscp af22
  match ip dscp af23
!
class-map match-any SILVER-DATA
  match ip dscp af11
  match ip dscp af12
  match ip dscp af13
!
policy-map WAN-EDGE
  class GOLD-DATA
    bandwidth percent 25
    random-detect dscp-based
  class SILVER-DATA
    bandwidth percent 15
    random-detect dscp-based
  class class-default
    fair-queue
    random-detect dscp-based
  
```



The diagram shows three overlapping cylinders representing queues. The top cylinder is yellow and labeled '25%'. The middle cylinder is grey and labeled '15%'. The bottom cylinder is red and labeled 'WRED on class-default'. The cylinders are arranged in a descending staircase pattern from top-left to bottom-right.

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## Provisioning Tools: Link-Fragmentation and Interleaving




Serialization can cause excessive delay

With fragmentation and interleaving serialization delay is minimized

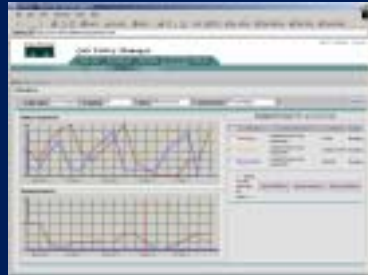
- serialization delay is the finite amount of time required to put frames on a wire
- for links  $\leq 768$  kbps serialization delay is a major factor affecting latency and jitter
- for such slow links, large data packets need to be fragmented and interleaved with smaller, more urgent voice packets

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## Management Tools: QPM and QDM



- QoS is efficiently scaled with a centralized management server
- QoS deployment is best followed by ongoing monitoring to ensure that targeted service-levels are being provided
- QoS policies need periodic tuning to adjust to changing business needs

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## hp OpenView performance insight for networks





- designed for network operations managers, service managers and their customers
- monitors network core and edge: interfaces, routers, Cisco/Bay device resources, frame relay, ATM, Cisco Powered Networks
- ensures network performance and availability
- documents current network performance for internal use and customer SLAs
- discovers network problems before they impact customers
- documents network performance to speed

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hp OpenView  
performance insight report packs

[click here](#) device reporting

[click here](#) interface reporting

[click here](#) ATM

[click here](#) frame relay

[click here](#) Cisco ping

[click here](#) NetFlow interfaces

[click here](#) service assurance

[click here](#) MPLS VPN

[http://www.managementsoftware.hp.com/products/performance/networks/Documentations/Product\\_HTML-555.asp](http://www.managementsoftware.hp.com/products/performance/networks/Documentations/Product_HTML-555.asp)

<http://www.hp.com/rnd/index.htm>


<http://www.hp.com/rnd/support/faqs/index.htm>

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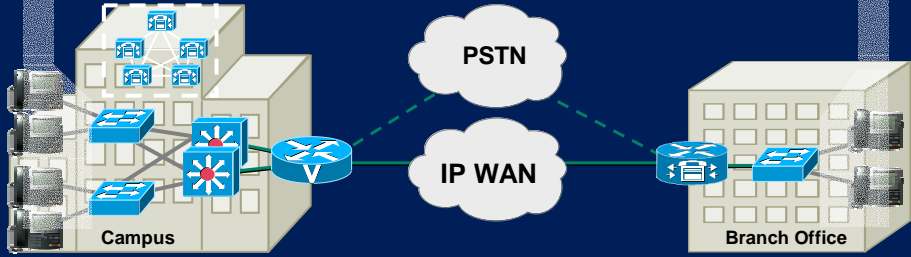
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## Design Approach to Enabling QoS



**Classification:** Mark the packets with a specific priority denoting a requirement for class of service from the network


**Trust Boundary:** Define and enforce a trust boundary at the network edge



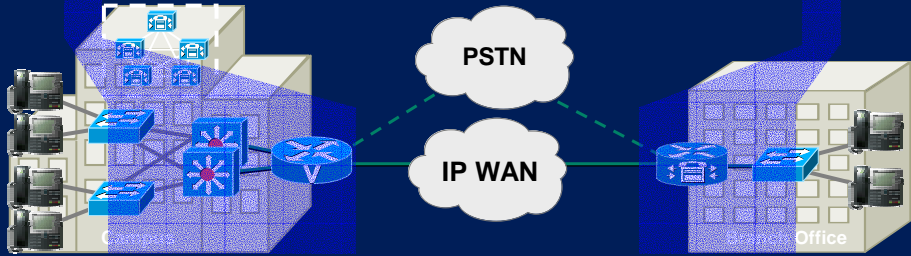
**QoS begins at the Campus Edge**

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## Design Approach to Enabling QoS, Cont.




**Scheduling:** Assign packets to one of multiple queues (based on classification) for expedited treatment throughout the network; use congestion avoidance for data



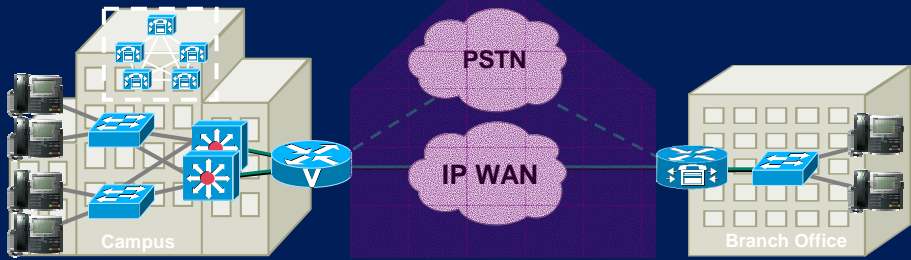
**Scheduling/Queuing takes place at every "hop" in the network**

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## Design Approach to Enabling QoS, Cont.




**Provisioning:** Accurately calculate the required bandwidth for all applications plus element overhead



**QoS can't solve everything; enough bandwidth must be provisioned for the number of voice/video calls and mission-critical applications**

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“

“Money and sex, storage and bandwidth: only too much is ever enough”

- Arno Penzias - Former Head of Bell Labs, and Nobel prizewinner

”

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