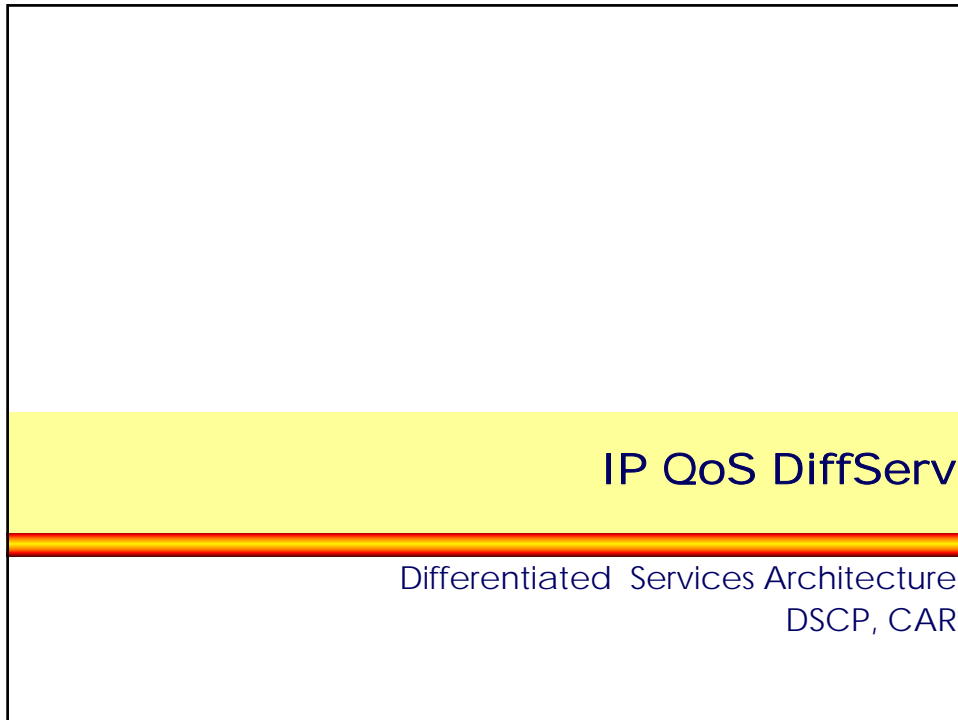


## L74 - IP QoS Differentiated Services Model



### Agenda

- **DiffServ Principles**
- **DS-Field, DSCP**
  - Historical Review
  - Newest Implementations
- **Per-Hop Behaviors (PHB)**
- **DiffServ in Detail**
- **DiffServ in other Environments**

## L74 - IP QoS Differentiated Services Model

### Principles

- **Integrated Services Model does not scale well**
  - flow based
  - traffic overhead (RSVP messages)
  - routers must maintain state information for each flow
- **ATM's principle of traffic classes**
  - seemed to be also useful for IP
  - note: ATM virtual circuits implicitly identify flows (connection between two end systems) but queuing management handles service classes only (CBR, VBR, ABR, UBR) -> all virtual circuits of same class use the same queue
- **Idea of Differentiated Services Model (DS, DiffServ):**  
**Packets are separated into traffic classes**
  - aggregation of traffic → better scalability!
- **Routers treat each traffic class according specific service level agreements**

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### Principles

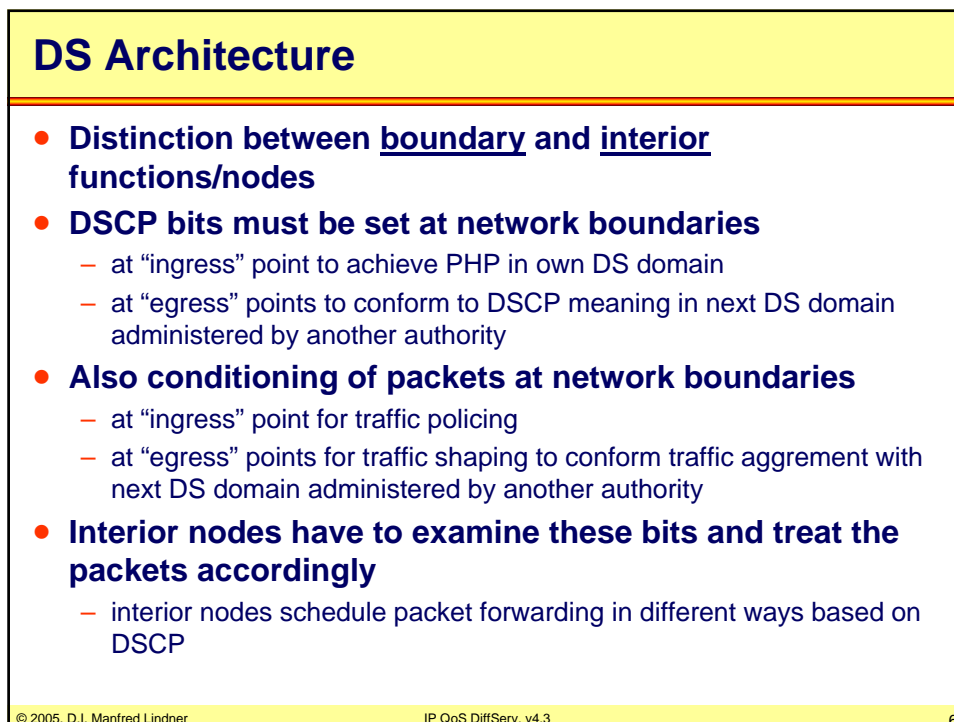
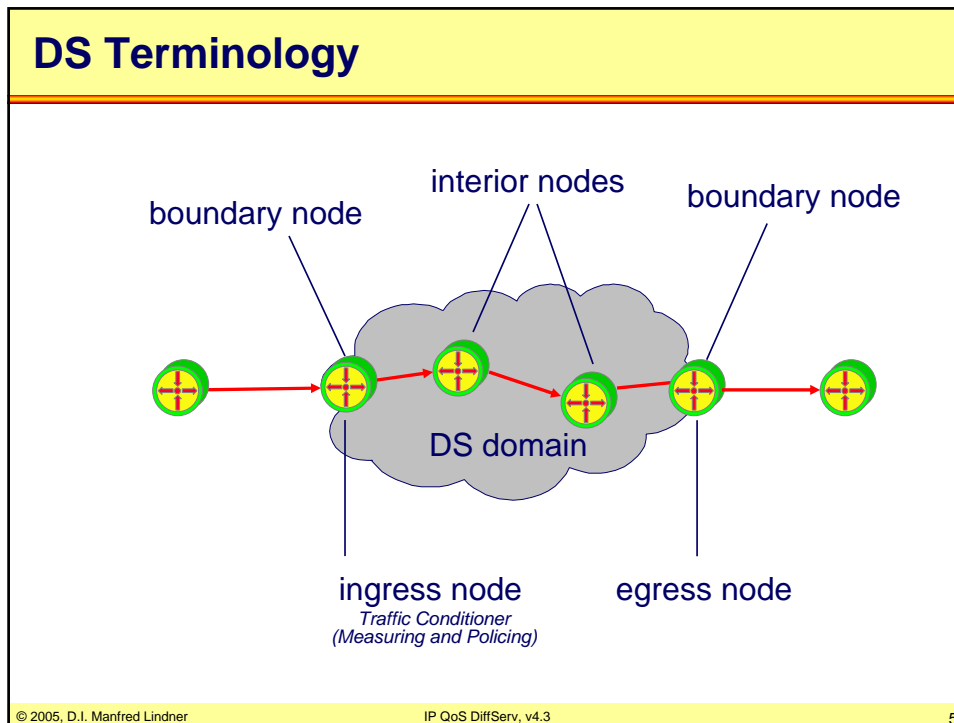
- **Requires a traffic identification and labeling (marking) mechanism**
- **Routers examine this label to adjust queuing and drop parameters**
  - IP Type of Service (ToS) field used as DS label
  - now called "Differentiated Service Code Point" (DSCP)
- **So there are two main DS building blocks:**
  - DSCP
  - Per-Hop Behavior (PHB) of the routers
- **No reservations necessary**
  - static QoS mechanism
  - PHB is determined by DSCP

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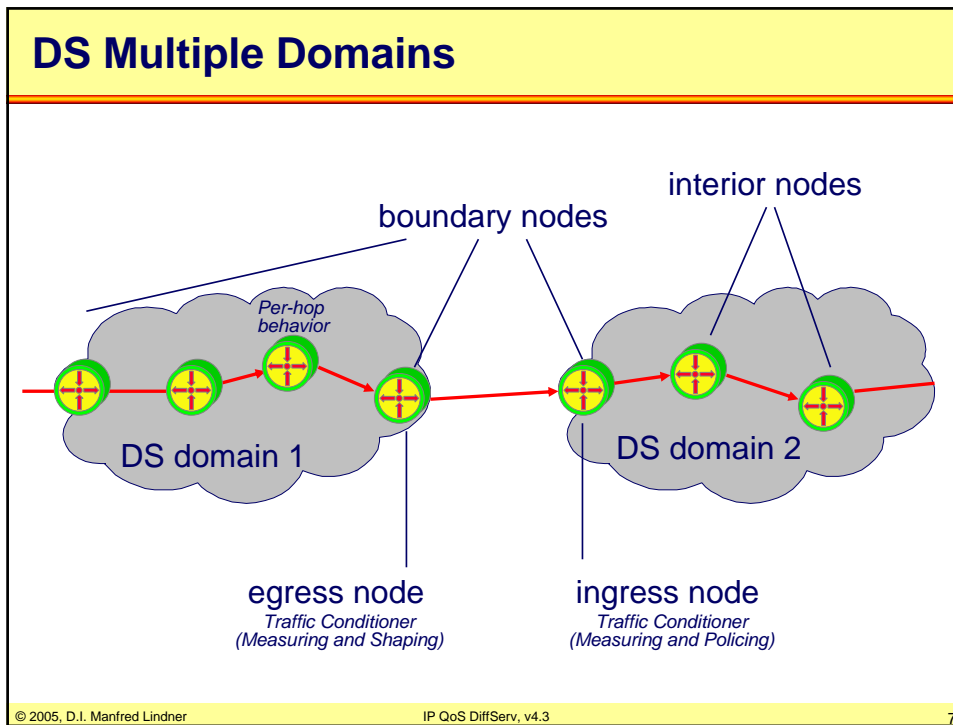
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## L74 - IP QoS Differentiated Services Model



## L74 - IP QoS Differentiated Services Model



- ### DS
- **DS requires routers to support sophisticated queue management**
    - DSCP value specifies queue parameters and drop preferences
    - traditional FIFO queuing cannot provide service differentiation
  - **DS assumes a “Service Level Agreement” between adjacent networks**
    - service provider and customer
    - between service providers
      - adapt different per-hop behaviors
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## L74 - IP QoS Differentiated Services Model

### Service Level Agreement / Specification

- **Service Level Agreement (SLA)**
  - in context to DS is a contract between customer and service provider that specifies the forwarding service
  - non-technical aspects
    - pricing
    - contractual obligations
  
- **Service Level Specification (SLS)**
  - a set of parameters and values
  - defines the service offered to a traffic stream by a DS domain
  - Traffic Conditioning Specification (TCS)
    - specifies a set of classifier rules

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### Traffic Conditioning Agreement

- **A Traffic Conditioning Agreement (TCA) consists**
  - classifier rules
  - traffic profiles (optional)
    - bandwidth, throughput, latency, drop precedence,...
  - metering, marking, discarding, shaping rules
  
- **A TCA is the result**
  - of an SLA
  - the specific service requirements
  - and the providers service provisioning policy

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## L74 - IP QoS Differentiated Services Model

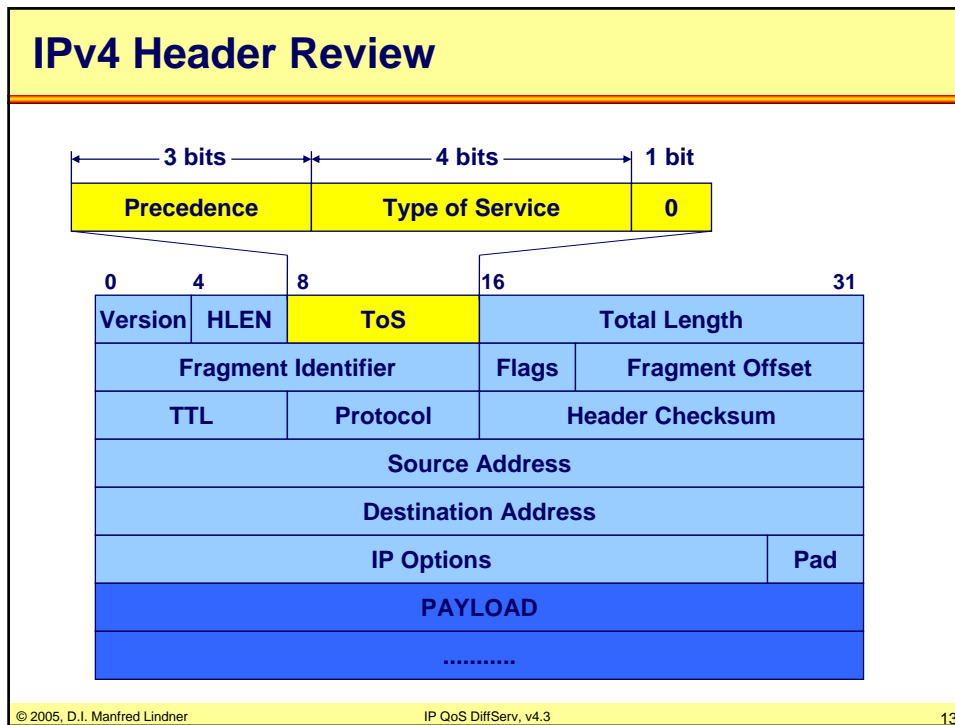
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### Providing a Label for DS

- **In earlier IP-days the IETF intended the Type of Service (ToS) field in the IP header to be used as some kind of flow descriptor**
  - rarely used, mostly even ignored by operating systems
- **So, this field can be reused !**
  - no additional header necessary
- **The IPv4 ToS field consists of**
  - three precedence bits for eight precedence levels (0...lowest, 7...highest)
  - four type of service indication bits
  - one unused bit

## L74 - IP QoS Differentiated Services Model



- ### IPv4 / IPv6 ToS Recycling
- IPv4 ToS field was redefined by the IETF to become the "Differentiated Service Code Point" (DSCP)
  - Now the DSCP field is used to label the traffic class of a flow
  - In IPv6 the "Traffic Class" octet is used to implement DiffServ
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## L74 - IP QoS Differentiated Services Model

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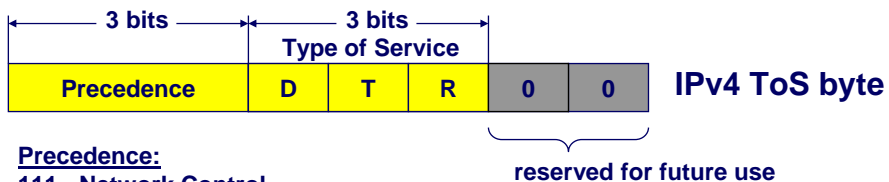
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### IPv4 ToS: Historical Review

- **1981: RFC 791 defines the Internet Protocol containing the original ToS-Field**



**Precedence:**

- 111 - Network Control
- 110 - Internetwork Control
- 101 - CRITIC/ECP
- 100 - Flash Override
- 011 - Flash
- 010 - Immediate
- 001 - Priority
- 000 - Routine

**Type of Service:**

- D:** delay (0 = normal / 1 = low)
- T:** throughput (0 = normal / 1 = high)
- R:** reliability (0 = normal / 1 = high)

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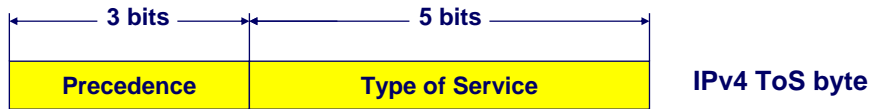
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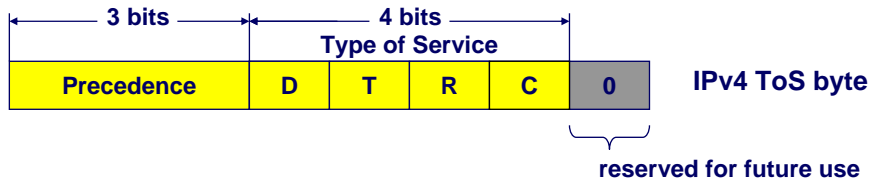
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### IPv4 ToS: Historical Review

- 1989: RFC 1122 defines ToS as a five bit field



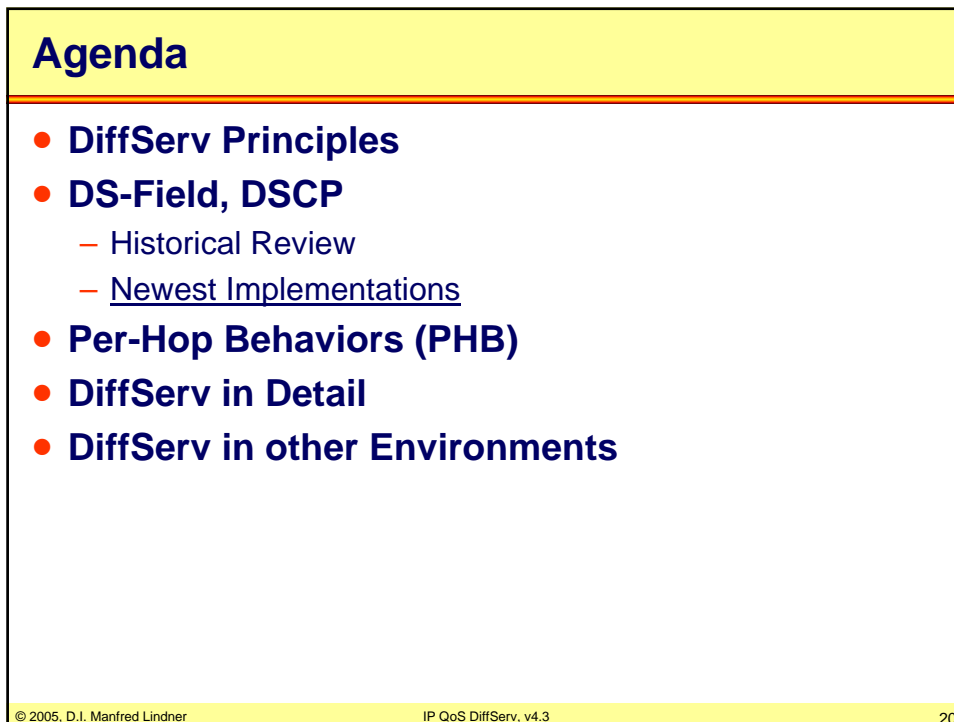
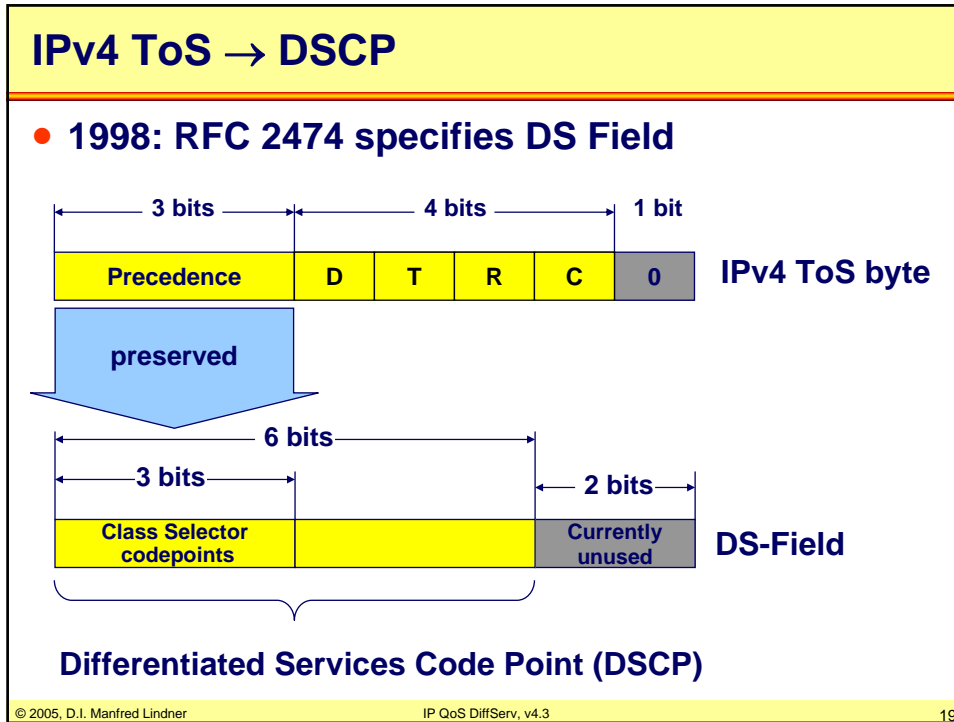
- 1992: RFC 1349 redefines the ToS-Field to be four bits



### Initial Meaning of the ToS Subfield

Type of Service	Bit Flags	Value	Examples
Low Latency	1000	8	Telnet keystrokes, urgent data, etc.
High Throughput	0100	4	FTP downloads, backups, bandwidth-sensitive applications
High Reliability	0010	2	File-sharing, database updates, UDP transactions
Low Cost	0001	1	NNTP news feed, nonessential traffic
Default	0000	0	Normal traffic

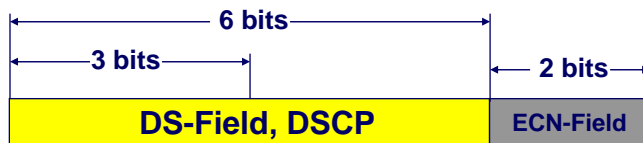
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## L74 - IP QoS Differentiated Services Model

### IPv4 ToS → newest development: ECN

- **2002: RFC 3260 declares Explicit Congestion Notification (ECN) as an integration of the former ToS-Field**



ECT    ECN-Capable Transport  
CE    Congestion Experienced

0	0	Not-ECT
0	1	ECT(1)
1	0	ECT(0)
1	1	CE

### ECN in detail

- **ECT(0) or ECT(1) are set by the data sender to indicate a ECN-capability**
  - routers treat both code points as equivalent
- **Not-ECT indicates a packet that is not using ECN**
- **CE code point is set by a router to indicate congestion to the end nodes**
- **Routers that have a packet arriving at a full queue drop the packet, just as they do in the absence of ECN**
  - see specifications
    - RFC 3168 "The Addition of ECN to IP"

## L74 - IP QoS Differentiated Services Model

### DSCP Usage

- **DS-routers overwrite the IPv4 ToS field**
  - only precedence bits are preserved
  - now known as "class selector code point" field
- **DSCP consists of 6 bits**
  - 64 code points possible:
    - 48 in global space, 16 for local use
  - last 2 bits of the former IPv4 ToS field used for ECN
  - specifications
    - RFC 2474: "Definition of the Differentiated Service Field in the IPv4 and IPv6 Headers"
    - RFC 2475: "An Architecture for Differentiated Services"
    - RFC 3260: "New Terminology and Clarifications for DiffServ"

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## L74 - IP QoS Differentiated Services Model

### Per-Hop Behavior

- **A Per-Hop Behavior (PHB) is**
  - "The externally observable forwarding behavior applied at a DS-compliant node to a DS behavior aggregate."
  - concerns local behavior of a network-node
  - should enable predictable services
- **The PHB describes various node-behaviors for incoming packets**
  - forwarding
  - classification
  - scheduling
  - drop
- **Note: Traffic conditioning and service provisioning is not part of a PHB definition**

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### Per-Hop Behaviors

#### 4 Types:

- **Default PHB (DE)**
  - Best Effort
  - DSCP = 000000
- **Class Selector PHB**
  - Defined to be backward-compatible with IP precedence

Precedence 1	001 000
Precedence 2	010 000
Precedence 3	011 000
Precedence 4	100 000
Precedence 5	101 000
Precedence 6	110 000
Precedence 7	111 000

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### Per-Hop Behaviors

- **Expedited Forwarding (EF)**

- Premium Service (Highest DS QoS)
- using a single DSCP only (101110)
- minimal delay and jitter; low loss and assured bandwidth
- targets applications like VoIP and video conferencing
  - virtual leased line service
  - looks like a point-to-point connection for DiffServ network's end nodes
- implementation by appropriate packet scheduling techniques
  - it must be ensured, that a busy EF queue does not starve the remaining traffic queues
  - e.g. CBWFQ (Class-Based Weighted Fair Queuing)
  - e.g. Priority Queuing

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### Per-Hop Behaviors

- **Assured Forwarding (AF)**

- emulates a lightly loaded network even in congestion cases
- 4 classes and 3 drop-precedence's within each class = 12 code points
  - bandwidth assurance but no guarantee
  - each traffic class is serviced in its own queue

Drop Precedence	Class 1	Class 2	Class 3	Class 4
Low	001 010	010 010	011 010	100 010
Medium	001 100	010 100	011 100	100 100
High	001 110	010 110	011 110	100 110

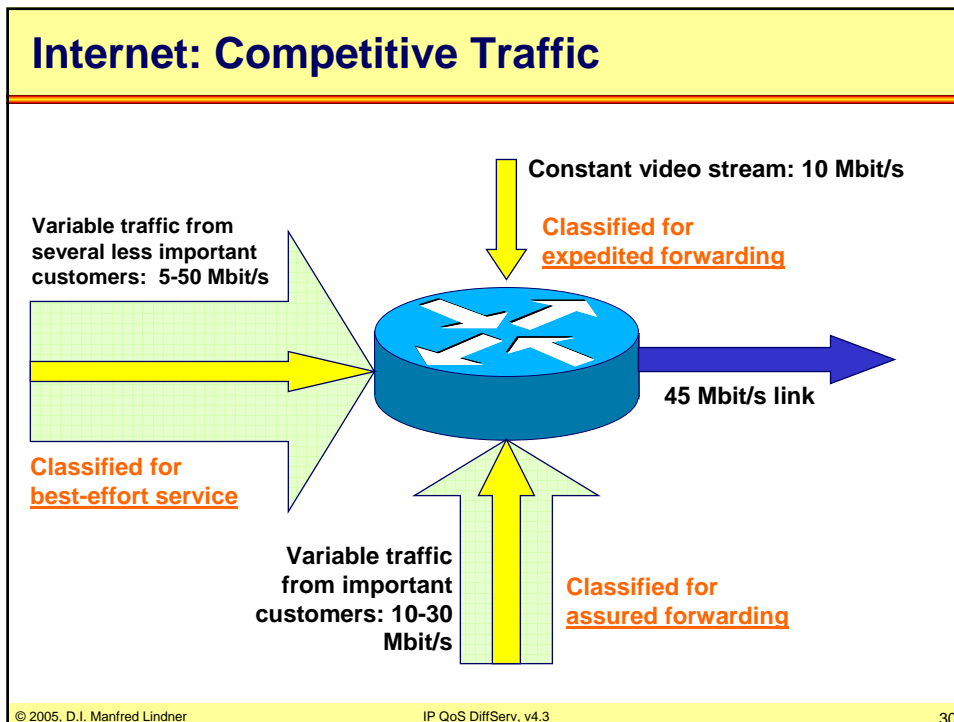
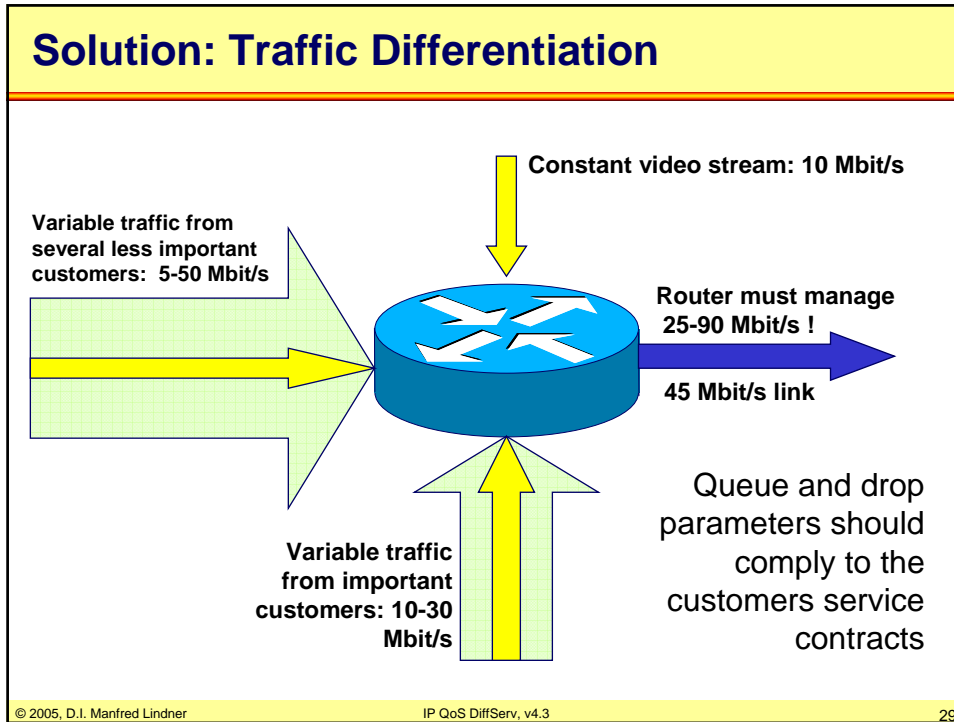
- Random Early Detection (RED)-queue management is often used for an implementation

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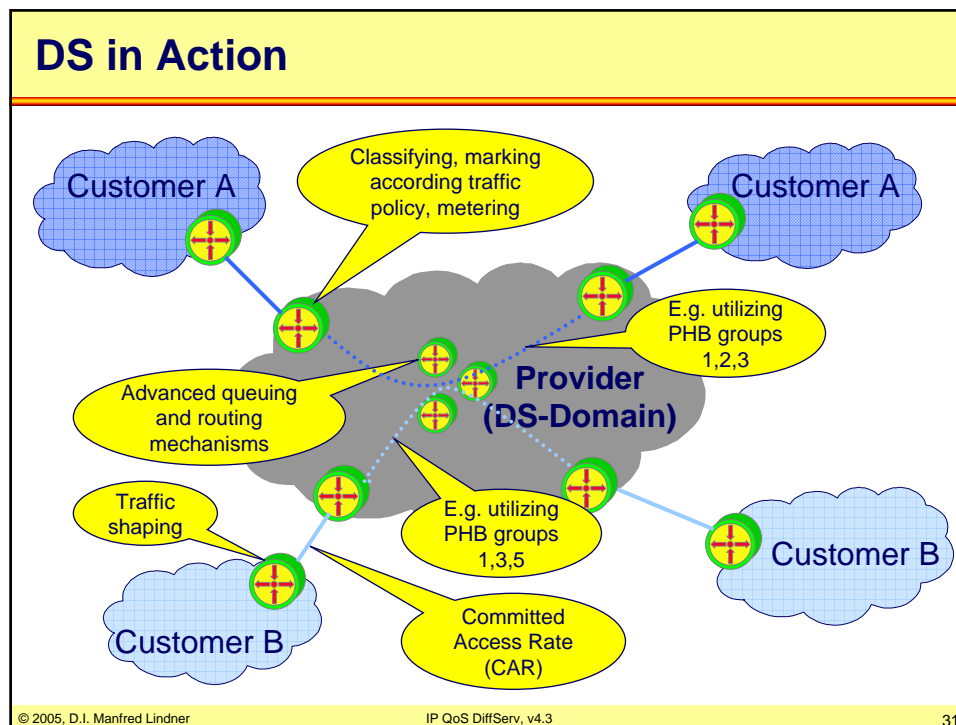
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## L74 - IP QoS Differentiated Services Model



## L74 - IP QoS Differentiated Services Model





## L74 - IP QoS Differentiated Services Model

### DS Domains

- A “DS domain” is a contiguous subnet with a consistent DS management
- A "DS region" consists of one or more contiguous DS domains
- Related PHB's are collected in a “PHB-group”
  - because there may be many more potential PHB's than the 64 map-able PHB's that can be addressed by the DSCP
  - e.g. several PHB's with similar properties can be summarized as one specific PHB group
    - sharing similar properties such as buffer sizes, bandwidth, delay, jitter, loss, etc.

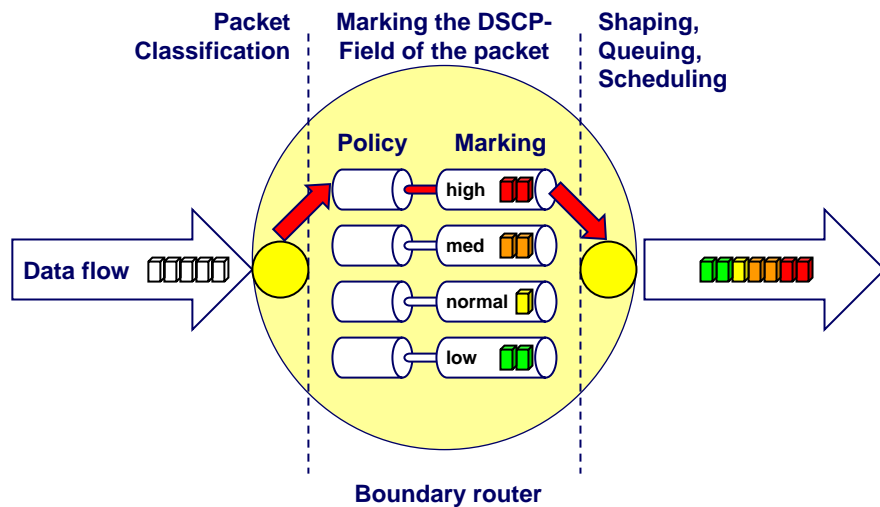
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### Boundary nodes

- Traffic Conditioning



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### Traffic Profiles

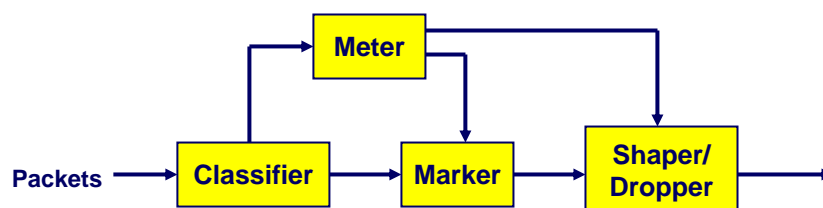
- **Classifiers check if incoming traffic profile complies to the SLA's traffic profile**
- **A traffic profile can be given by token-bucket parameters**
  - eg. "DSCP=x, use token-bucket r, b" specifies that all packets with DSCP=x should be measured against a token bucket meter with rate r and burst size b.
  - out-of-profile traffic: when packets arrive while there is currently no token available
- **Solution against out-of-profile traffic:**
  - DSCP remarking
  - traffic shaping: queuing to adapt token rate
  - packet dropping

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### Traffic Conditioner



Traffic conditioners are usually located within DS ingress and egress boundary nodes

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## L74 - IP QoS Differentiated Services Model

### Traffic Conditioner

- **Classifier**

- selects a packet in a traffic stream based on the content of some part of the packet header
  - common way: classification based on the DSCP field

- **Meter**

- measures traffic stream against traffic profile
  - based on traffic descriptor such as a token bucket
- the state of the Meter influences the decision of the Marker and the Shaper/Dropper

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### Traffic Conditioner

- **Marker**

- might be configured to mark all packets which are steered to it (by the classifier) to a single DSCP
- might select a PHB in a PHB group according to the meter's state
- might re-mark (change an existing DSCP)

- **Shaper**

- delays some or all packets in a traffic stream to smooth bursts and cares for compliance with the specified traffic profile

- **Dropper**

- discards all packets that doesn't comply with the traffic profile ("policing the stream")

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## L74 - IP QoS Differentiated Services Model

### Packet Classification

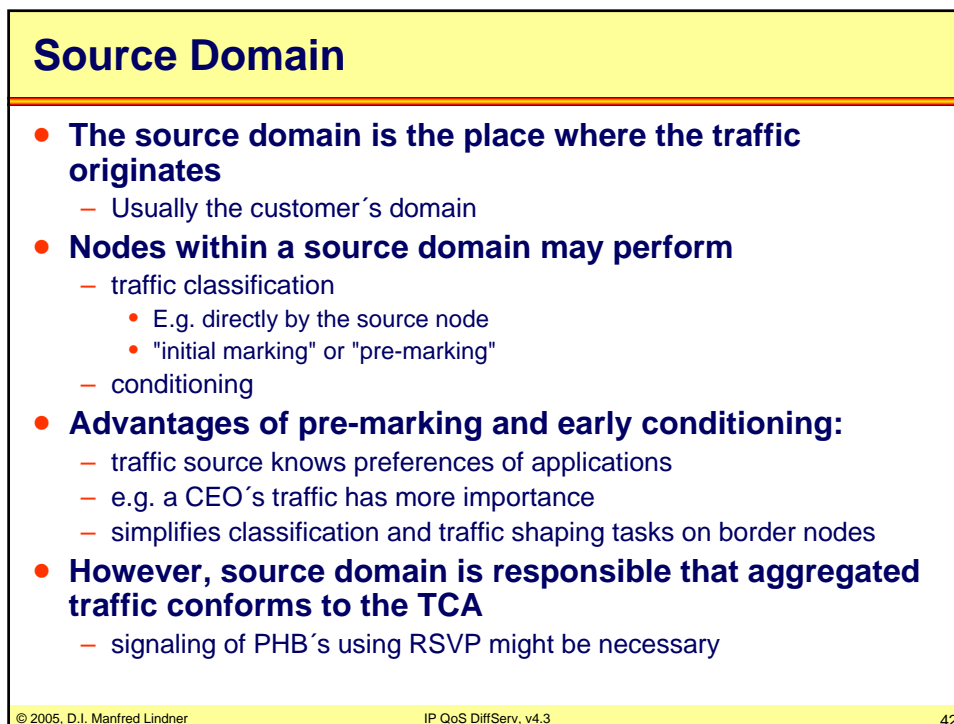
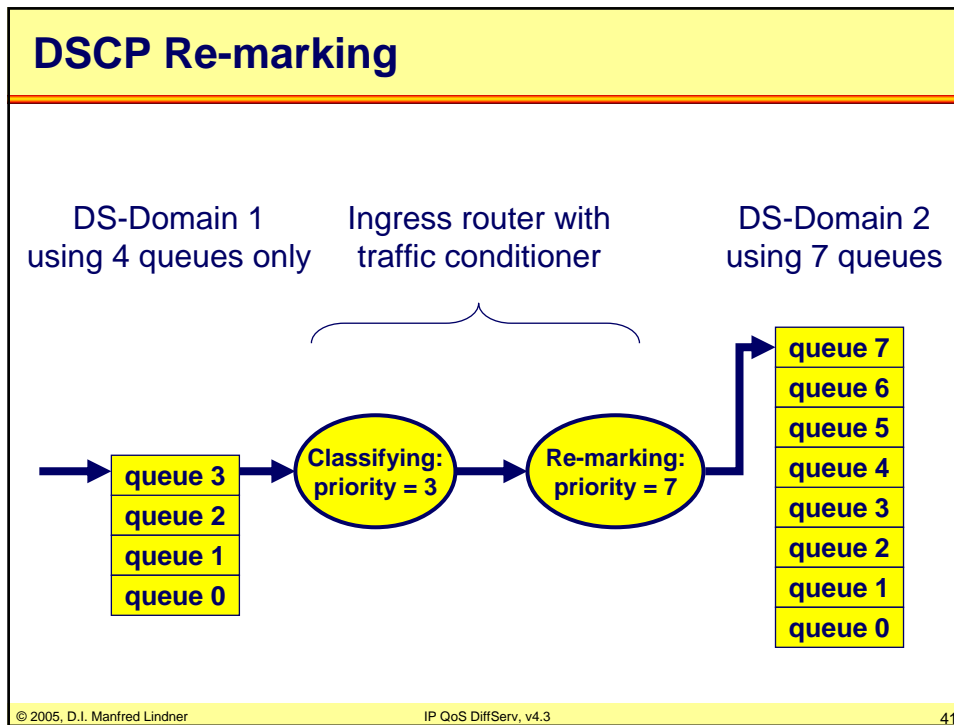
#### Two types of classifiers:

- **Behavior Aggregate (BA) classifier**
  - classifies packets based on the DSCP only
- **Multi-field (MF) classifier**
  - selects packets based on the value of a combination of one or more header fields
  - e.g. source and destination address, DSCP, protocol ID, ports, also incoming interface
  - note: IP fragmentation can lead to wrong MF classification of fragments if TCP fields are examined

### Re-marking the DSCP

- **Ingress routers must ensure that packets entering a DS domain receive the same QoS as in the domain before**
  - extending the PHB group by re-marking the DSCP field and traffic conditioning
- **Ingress router examines the TCP port numbers and assigns a new service class**
- **So, the DS is transparent to applications**
  - note: IntServ requires application's help !
- **However, an end-to-end QoS cannot be guaranteed**
  - because no reservation of resources
  - "Soft" QoS

## L74 - IP QoS Differentiated Services Model



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### Multicast Traffic

- **IP multicast traffic may cause a higher load inside a DS domain**
  - multicast packets may take multiple paths simultaneously because of multicast packet replication
  - unpredictably consumes more network resources than unicast packets
- **So it may be necessary to reserve different sets of DSCP for unicast and multicast traffic**
  - to provide resource isolation from multicast traffic

## L74 - IP QoS Differentiated Services Model

### QoS Mapping between IEEE 802 and IP

- **802.1p and 802.1Q define 8 levels of prioritization (0-7)**
- **DSCP class selector code point also provides 8 precedence levels**
  - three-bit field within DSCP
- **So 802.1p priority values can be mapped one-to-one into the DS class selector code point**

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### DS and IPsec

- **IPsec does not use the DS field of the IP header for its cryptographic calculations**
  - That is: IPsec can be used in DS networks without modifications
- **DS together with IPsec tunneling hides port information**
  - increases security
  - as routers only need to examine the DSCP to perform traffic differentiation

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## L74 - IP QoS Differentiated Services Model

### DS and IPsec

#### IPsec tunnel mode:

- encapsulates the whole IP packet with an outer IP header
- outer IP header contains a proxy-DS field which is set according to the SLA
- only this outer proxy-DS field will be modified on the way through the IPsec tunnel
- at the end of the IPsec tunnel the outer IP header is stripped off again