CS/ECE 438: Communication Networks

Internet QoS

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Introduction

- The Internet only provides a ‘best effort’ service model
  - It does not provide any guarantee in terms of delay and/or bandwidth.
- This service model is not suitable for many applications
  - Interactive sessions like live audio/video conferencing, real-time applications require strict delay and bandwidth guarantee

Quality of Service (QoS)

- QoS is all about providing different class of services in IP networks
  - Each class may support different subclasses
- Applications and/or users will specify the service they require from the network and the network will provide that.
- QoS is a superset of ‘best effort’ service model
  - It requires additional features/mechanisms on the end host and routing devices

QoS Architechtures

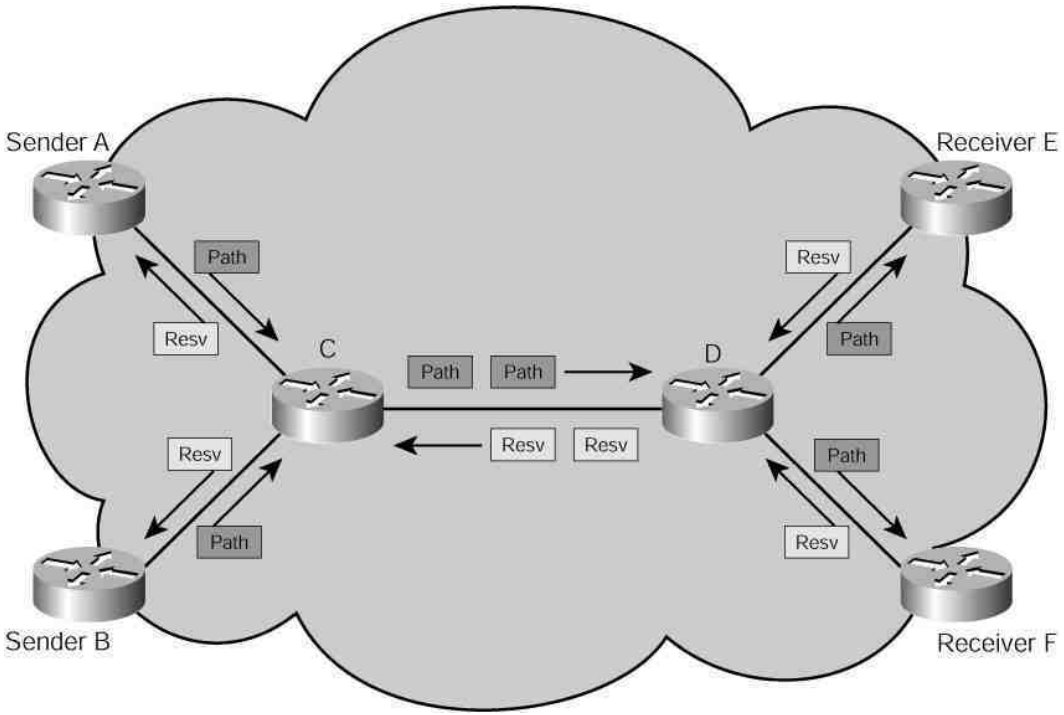
- There are two prominent architectures for QoS:
  - Integrated Services (IntServ)
  - Differentiated Services (DiffServ)
- They differ in their granularity of service
  - IntServ provides per flow guarantees
  - DiffServ provides aggregated service classes
- DiffServ is more popular than IntServ
  - IntServ is not scalable and incremental deployment is not possible

Integrated Services (IntServ)

- Packets with same source, destination IP address, port number and protocol number are identified as flows
- Two level of service class for each flow:
  - **Controlled load service**: as good as an unloaded network
  - **Guaranteed service**: provides firm guarantees
- Makes use of **Resource Reservation Protocol (RSVP)**
  - RSVP reserves resources for a particular flow in all the routers in a particular path between a source and destination
  - All the in-path routers must store per flow resource reservation information
- IntServ has scalability and deployment problem
  - This is an end-to-end model
  - All in-path routers must also classify packets into flows

IntServ: Mechanism

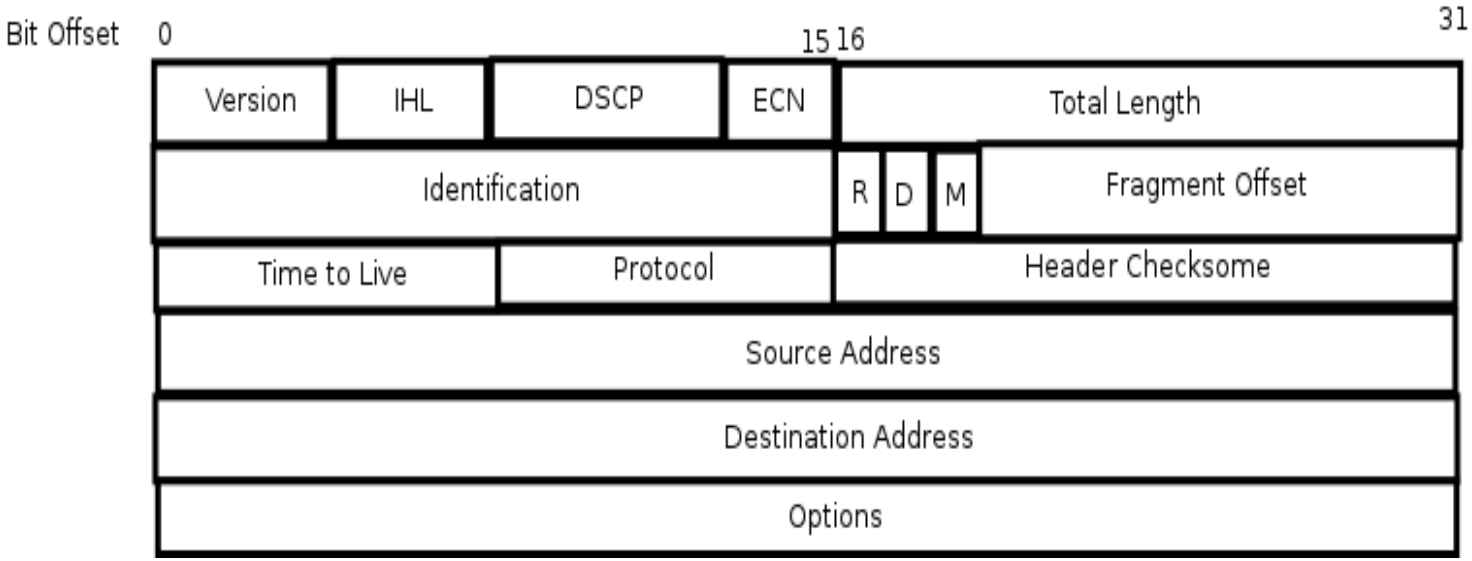
- **Signaling and/or admission control**: A signaling protocol RSVP is required for reservation of resources. Admission control blocks incoming traffic if the desired QoS cannot be met.



Differentiated Services (DiffServ)

- Provides per hop behavior instead of end-to-end
  - No signaling/reservation needed.
  - No need to classify packets into flows
- Support a small number of forwarding classes at each router
  - Service models to be accomplished through provisioning
- Edge routers map packets into forwarding classes based on service level agreement (SLA).
  - Forwarding class is encoded in the packet header.
  - Six bits in the TOS file in the IP packet is used in DiffServ:
    - Examples of forwarding classes:
      - 101 110 - **Expedited Forwarding**
      - 010 010 - **Assured forwarding**
  - Problems with DiffServ:
    - end-to-end service guaranteed is hard to

DiffServ Code Point (DSCP)

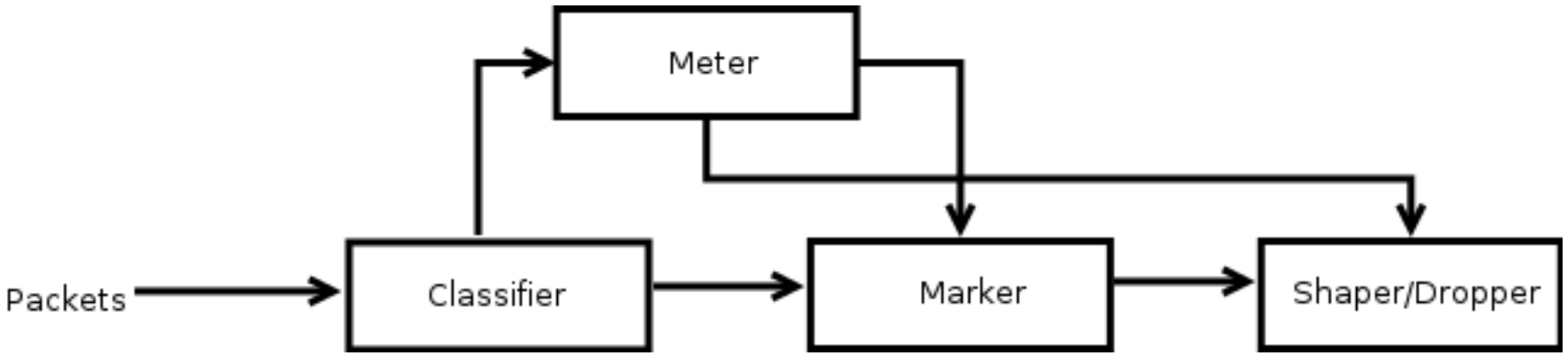


Mechanisms for QoS

- The mechanisms need to be in place to augment the network with QoS capabilities:
  - **Signaling and/or admission control**: A signaling protocol is required for reservation of resources. Admission control blocks incoming traffic if the desired QoS cannot be met.
  - **Packet classification/marking**: *Packet* classifiers select packets in a traffic stream based on the content of some portion of the packet header
  - **traffic conditioning**. Traffic conditioning performs metering, shaping, policing and/or re-marking to ensure that the traffic entering the DS domain conforms to the rules

Mechanisms Contnd..

- **Marking:** the process of setting the DS codepoint in a packet based on defined rules; pre-marking, re-marking.
- **Metering:** the process of measuring the temporal properties (e.g., rate) of a traffic stream selected by a classifier
- **Shaping**: the process of delaying packets within a traffic stream to cause it to conform to some defined traffic profile.



Assure Forwarding (AF)

- A general use DiffServ Per-Hop-Behavior (PHB) Group defined by RFC 2597
  - The AF PHB group provides delivery of IP packets in four independently forwarded AF classes
  - Within each AF class IP packets are marked with one of three possible drop precedence values
- In a DS node, the level of forwarding assurance of an IP packet thus depends on
  - how much forwarding resources has been allocated to the AF class that the packet belongs to
  - what is the current load of the AF class, and, in case of congestion within the class
  - what is the drop precedence of the packet.

AF Example

- Recommended values of AF DS code points (DSCP)

AF11 = '001010', AF12 = '001100', AF13 = '001110',
AF21 = '010010', AF22 = '010100', AF23 = '010110',
AF31 = '011010', AF32 = '011100', AF33 = '011110',
AF41 = '100010', AF42 = '100100', AF43 = '100110'.

	Class 1	Class 2	Class 3	Class 4
Low Drop Prec	001010	010010	011010	100010
Medium Drop Prec	001100	010100	011100	100100
High Drop Prec	001110	010110	011110	100110

Example AF configuration

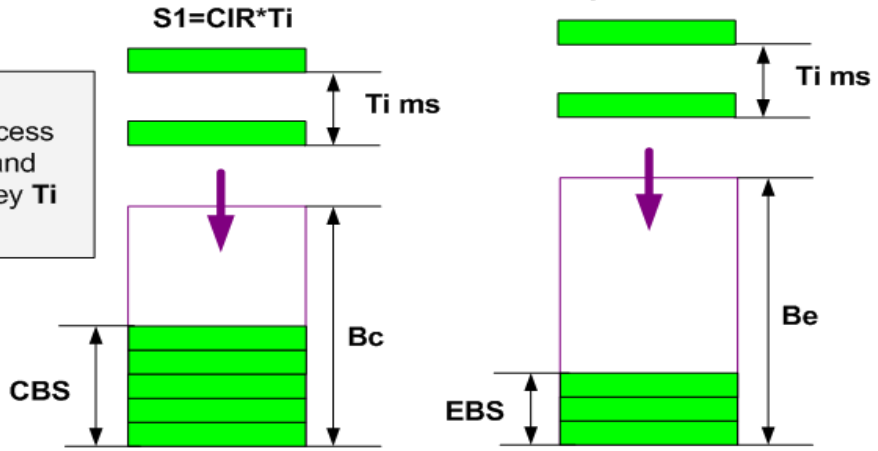
		Subclass 1		Subclass 2		Subclass 3	
Class	Resources	In	Out	In	Out	In	Out
1	40%	2%	50%	3%	60%	4%	70%
2	25%	2%	60%	4%	80%	5%	80%
3	20%	3%	70%	5%	80%	10%	90%
4	15%	3%	100%	6%	100%	10%	100%

- The drop precedence level of a packet could be assigned, for example, by using a **token bucket /leaky bucket** traffic policer, which has as its parameters a rate and a size, which is the sum of two burst values: **a committed information rate (CIR)** and **Peak Information Rate (PIR)**

- **Token Bucket Animation**

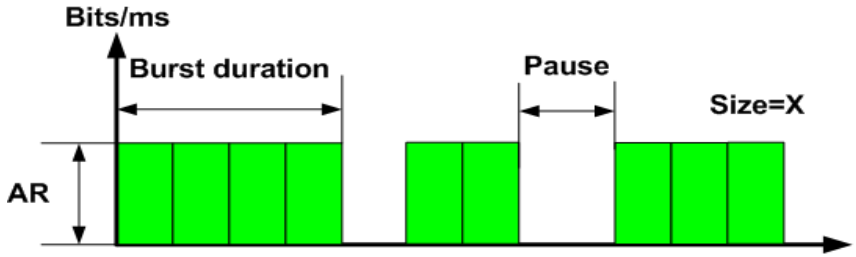
Token Bucket Usage

Token Refill
Buckets are filled separately. The process adds **CIR*Ti** bytes to the first bucket and **PIR*Ti** bytes to the second bucket evey **Ti** milliseconds.



Metering(X)

```
If(EBS < S) then
  Packet Violates;
Else if (CBS < S) then
  Packet Exceeds;
  Size1=Size1-S;
Else
  Packet Conforms;
  CBS=CBS-S;
  EBS=EBS-S;
End if.
```



Packet flow
Bursts enter metering space at rate **AR** each. However, pauses between frames allow buckets to refill.

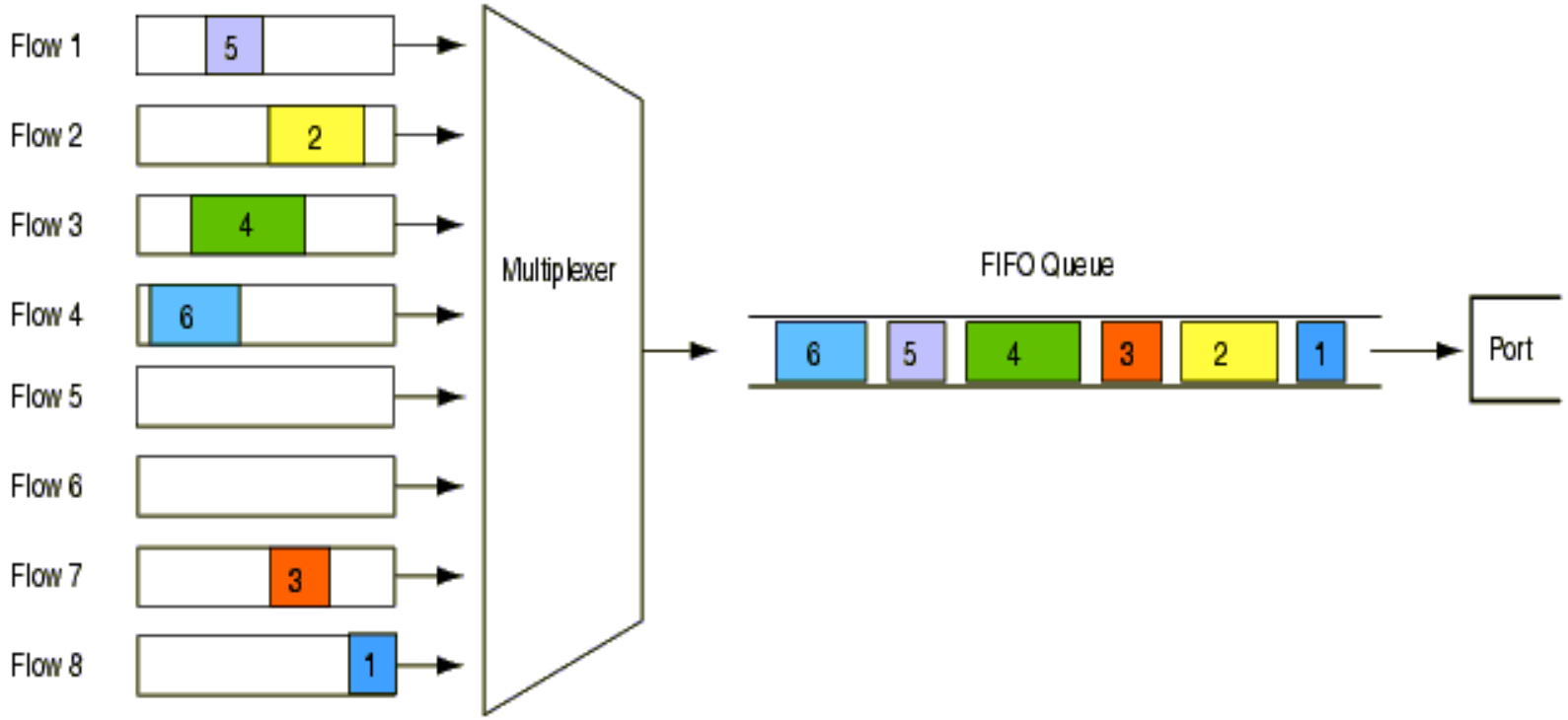
Expedited Forwarding (EF) PHB

- The EF PHB (RFC 2475) can be used to build a low loss, low latency, low jitter, assured bandwidth, end-to-end service through DS domains.
  - Codepoint 101110 is recommended for the EF PHB.
- Creating such a service has two parts:
  - Configuring nodes so that the aggregate has a well-defined minimum departure rate. ("Well-defined" means independent of the dynamic state of the node. In particular, independent of the intensity of other traffic at the node.)
  - Conditioning the aggregate (via policing and shaping) so that its arrival rate at any node is always less than that node's configured minimum departure rate.

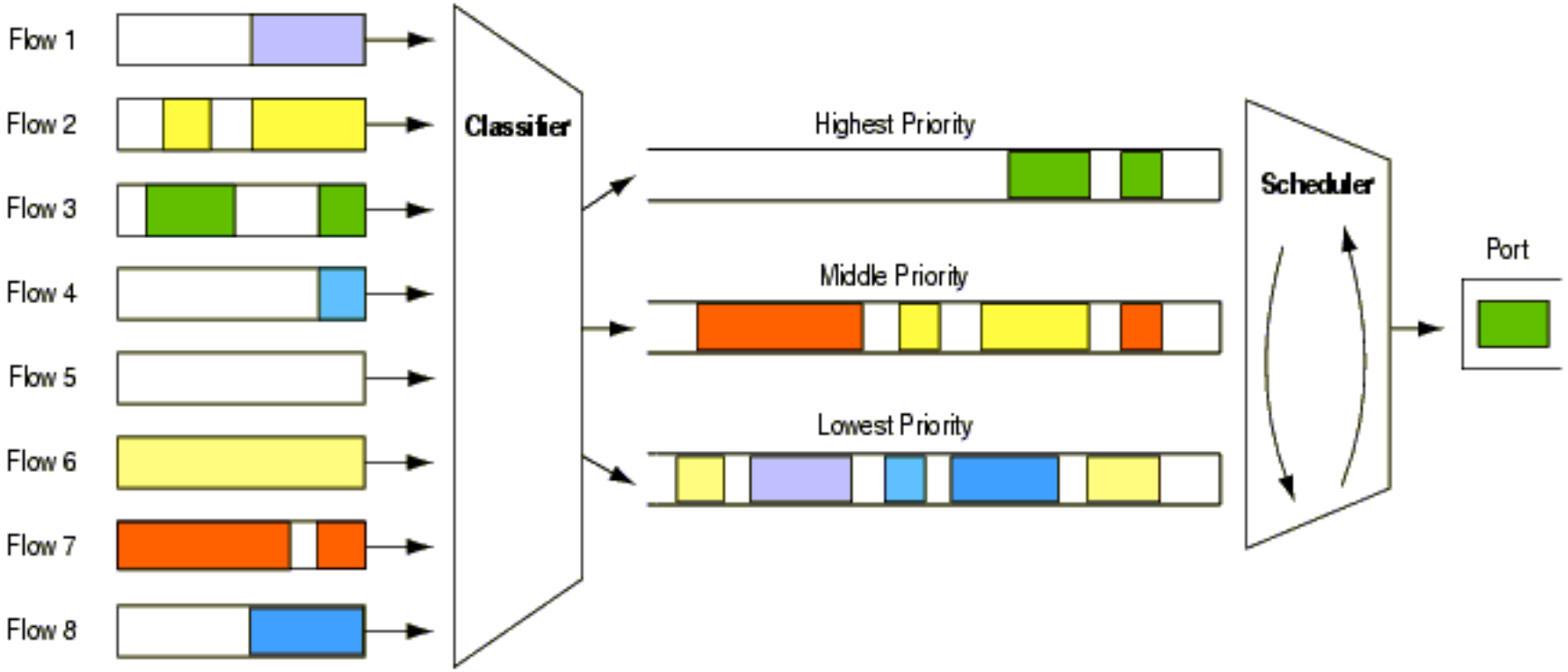
AF/EF Queuing Mechanism

- Several types of queue scheduling mechanisms may be employed to deliver the forwarding behavior:
  - *Class Based Queue (CBQ)*
  - *Token Bucket Flow (TBF)*
  - *Clark-Shenker-Zhang (CSZ)*
  - *First In First Out (FIFO)*
  - *Priority Traffic Equalizer (TEQL)*
  - *Stochastic Fair Queuing (SFQ)*
  - *Asynchronous Transfer Mode (ATM)*
  - *Random Early Detection (RED)*
  - *Generalized RED (GRED)*

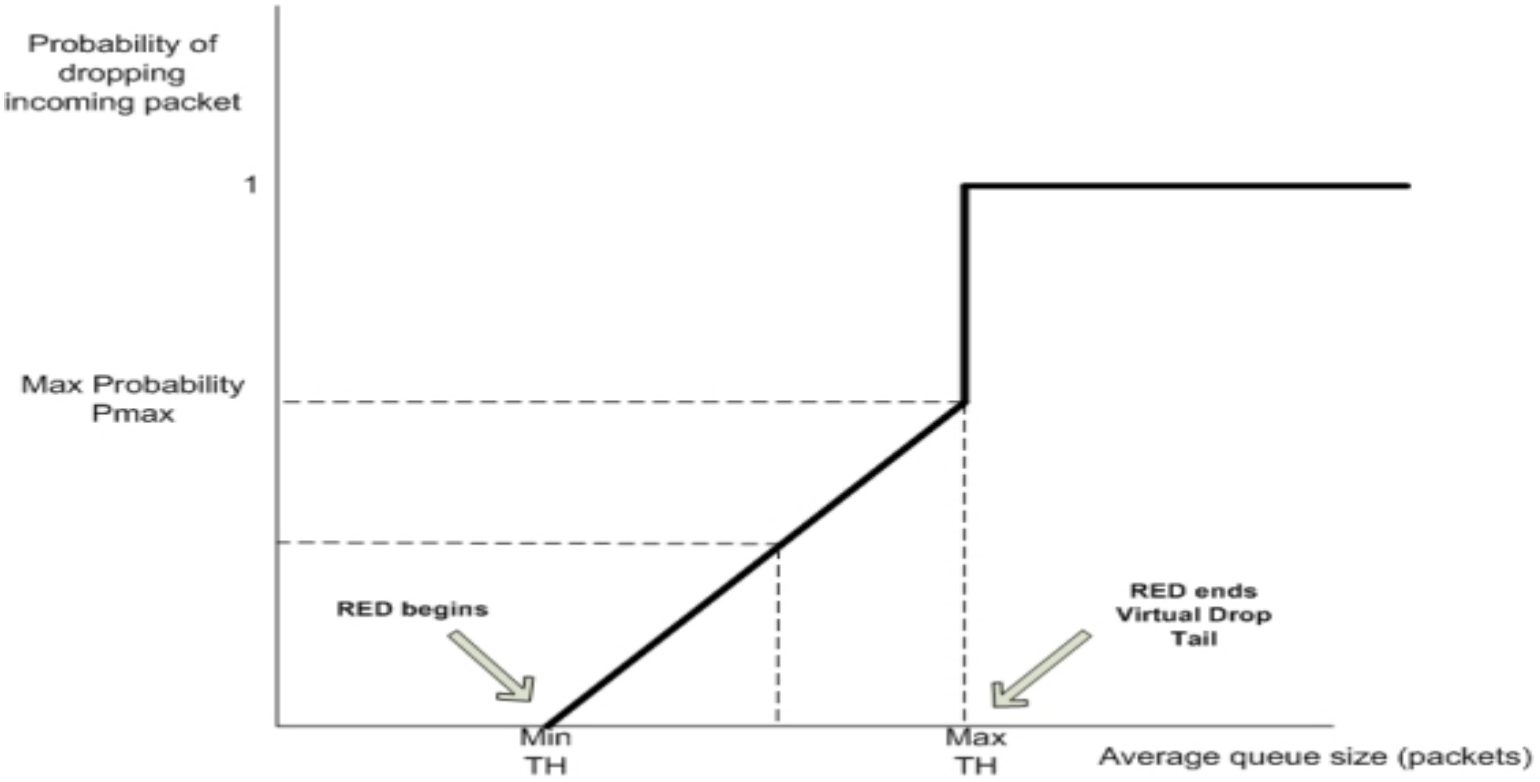
FIFO Queuing



Priority Queuing



Random Early Drop (RED) Queuing



Other approaches to QoS

- Multi Protocol Label Switching (MPLS)
- Traffic Engineering
- Constraint Based Routing
- Software Defined Networking

Critics of QoS

- QoS is a highly debated issue
- Its unlikely that Internet wide QoS will ever be deployed
- On the other hand, QoS has been hugely successful in private/enterprise networks
- Net-neutrality vs QoS is an ongoing issue.

Questions?

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