S−38.180 Palvelunlaatu Internetissä

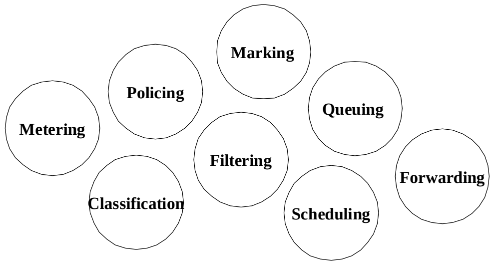
S−38.180 Quality of Service in Internet

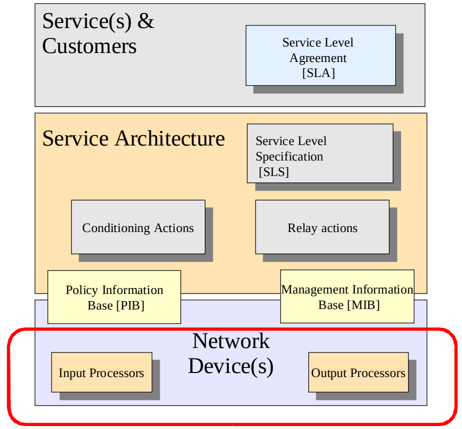
Luento 3: Mekanismit − osa 1

Lecture 3: Mechanisms − part 1

Today’s Topic

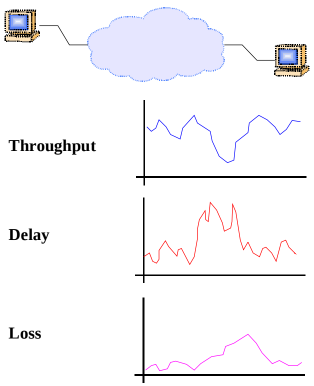
- This lecture is about functional mechanisms which can be found from the input/output processors of network devices





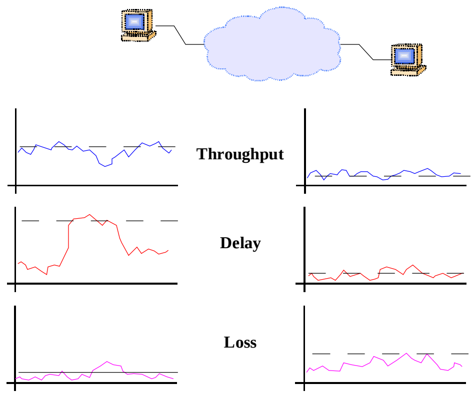
Internet Service

- Internet service is packet delivery service − pretty much like common snailmail service
  - Datagrams are delivered as individual items and they experience service which varies as a function of time



Internet Service

- By adding QoS, we are aiming to provide differentiation to this situation
- Differentiation can be based on different criterion
  - Usage
  - Money
  - Status



Terminology

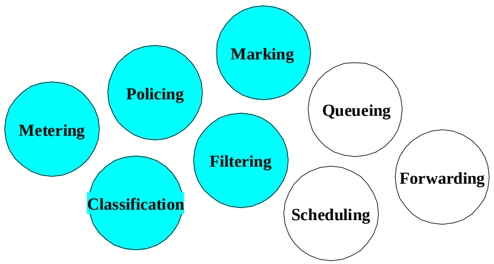
- **Connection**: is dynamically formed reservation of network resources for a period of time.
  - Connection requires a state to be formed inside the network
  - State is a filter defining packets which belong into particular connection and required reservation attributes
- **Flow**: is formed from arbitrary packets which fall within predefined filter and temporal behavior.
  - Packets from one source to same destination arrive to investigation point with interarrival time less than ***t*** seconds.

Terminology

- **Aggregate**: is a group of flows which have same forwarding characteristics and share link resources.
- **Class**: is a group of connections which share same forwarding characteristics.

Input processor

- Input processor of Internet router consists several mechanisms
  - Filtering
  - Classification
  - Metering
  - Policing
  - Marking
  - Shaping

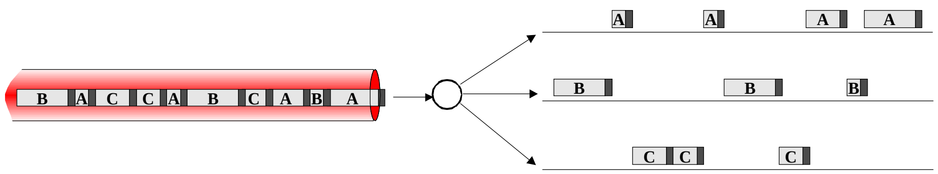


Classification

- Individual connections can be recognized by looking sufficient number of protocol fields.
- This is used in Integrated Services architecture.
- IntServ uses reservation protocol for informing the network about fields which should be examined.
- If per connection accuracy is not needed or can not be feasibly implemented is class based operation the answer.
- This is used in Differentiated Services architecture.
- Class is based on static filters covering broad range of different connections i.e. aggregating connections to one logical unit

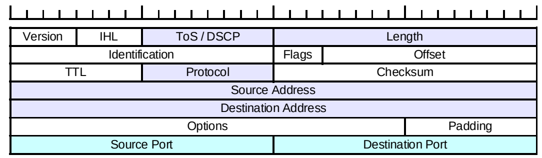
Classification

- Classification is process where packets in the packets stream are separated into ***n*** logically separate packet streams.
- These streams are then treated as separate entities for which different actions are performed
- Separation is based on filters which match packet content to the filtering rules.



Filtering

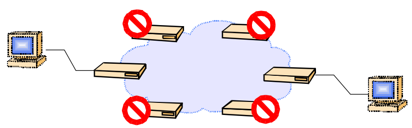
- Commonly filters are based on IP packet / transport header information
  - IP addresses
  - Protocol information
  - DSCP−field
  - Port information
  - Length information



- Generally any fixed block of bits can be used as a filter

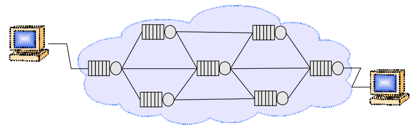
Service Level Management

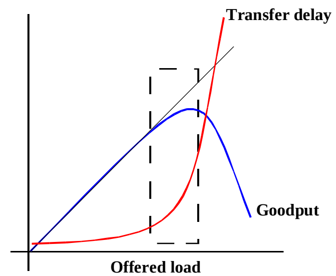
- QoS based networks need careful management
  - How to provision the network so that there will not be unnecessary queuing or packet loss
  - How to control the amount of traffic that gets into the network
- Network level
- Customer level / connection level
- Packet level



Service Level Management

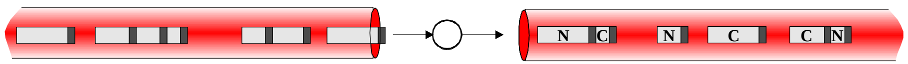
- Overall objective is to offer QoS and/or maximize network throughput
- This requires
  - Limiting user traffic to the level that individual links operate on optimal fashion
  - Individual links can not be fully utilized
    - Unequal capacities
    - Uncertainty of paths
    - Uncertainty of demands





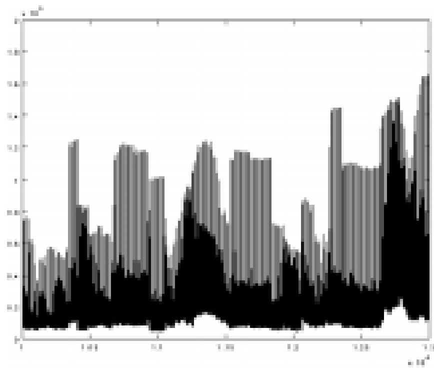
Rate Control

- Task is to decide which user packets should be delivered into the network and on what priority (mark)
  - They do not violate QoS management principles within the network by overloading the network
- Rate control operates in three levels
  - Measures the traffic
  - Compares the measured information to information in user / network policy
  - Executes policy based on comparison results
    - Marking
    - Dropping
    - Shaping



Rate Control

- User traffic process is largely dependent on application which is used.
  - Some applications produce constant traffic stream
    - Fixed size packets
    - Constant interarrival times
  - Other may produce bursts of packets
    - Variable size packets
    - Variable interarrival times



Rate Control

- Objectives:
  - Simple
    - Easy algorithm
    - Few parameters
  - Accurate
    - Actions are correct
    - Actions are transparent
    - Actions are immediate
  - Predictable
    - Action are consistent from time to time
- Requires:
  - Parametrization of user traffic
    - Either flow level
    - Or Aggregate level
  - This is bound to SLA made with the ISP

Metering

- Packet stream is measured to find out some of the following parameters:
  - Peak rate − maximum rate on which user is sending
  - Sustained rate − average rate on which user is sending
  - Burst size − maximum burst size which user sending on either with peak or average rate
- Actual measurement of information may be based on
  - Continuous time measurement
  - Discrete event analysis
  - Window based analysis

Token Bucket

- Produces information whether arrival rate is more or less than the threshold
- Algorithm is based on
  - Number of tokens in token bucket (in bytes)
  - Arrival time (T_{Now}, $T_{Last\ Arrival}$)
- Two limiting parameters
  - Bucket size (S)
  - Token rate (R) * token size

Initial condition:

$Number\ of\ Tokens = S$

Upon each arrival:

$Increment = TokenSize \cdot R \cdot (T_{Now} - T_{Last\ Arrival})$

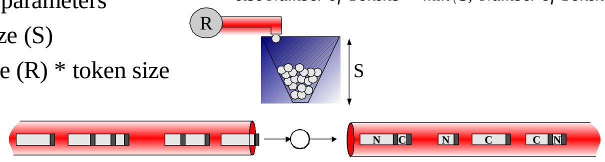
$Decrement = PacketLength$

$Conformance = Number\ of\ Tokens + Increment - Decrement$

$if\ Conformance \geq 0$

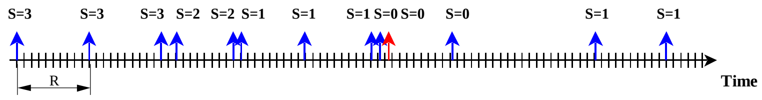
$then\ Number\ of\ Tokens = min(S,\ Conformance)$

$else\ Number\ of\ Tokens = min(S,\ Number\ of\ Tokens + Increment)$



Token Bucket

- In ideal situation
  - Packets arrive with intervals of token generation rate (R)
  - Packets are size of token
  - Variation of arrivals is compensated with bucket size (S)
    - Allows bursting
- Example:
  - R=10
  - S=3



Packet per packet EWMA meter

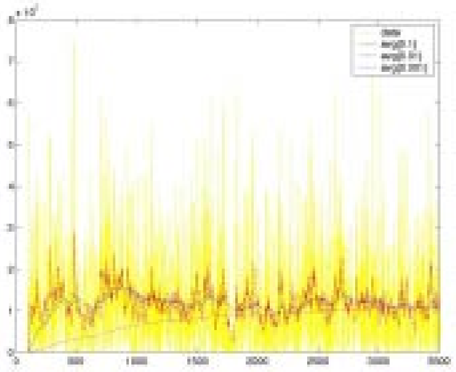
- Measures packet stream by using exponentially weighted moving average filter.
  - Tunable by parameter
    - Memory (ϵ)

Initial condition:

$avg(0) = 0$

After every packet arrival

$$avg(n+1) = (1-\epsilon) \cdot avg(n) + \epsilon \cdot \frac{PacketLength}{t_{n+1} - t_n}$$



Windowed EWMA meter

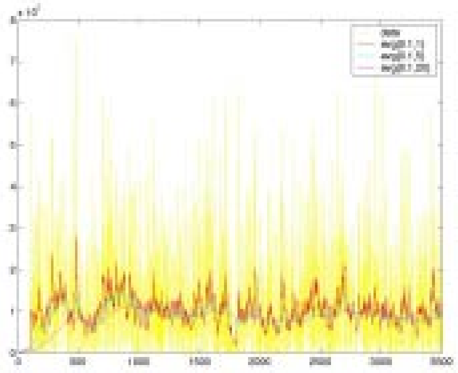
- Measures packet stream by using exponentially weighted moving average filter with sampling window.
  - Tunable by parameters
    - Memory (ϵ)
    - Sampling interval (ΔT)

Initial condition:

$avg(0) = 0$

After every ΔT time units

$$avg(t_{n+1}) = (1-\epsilon) \cdot avg(t_n) + \epsilon \cdot bytes\ during[t_{n+1}, t_n]$$



Time Sliding Window Meter

- TSW is memory based, windowed average rate estimator
- Tunable by parameter
  - Window length

Initial condition:

$avg(0)=0$

$Win_{length}=C$

$T_{front}=0$

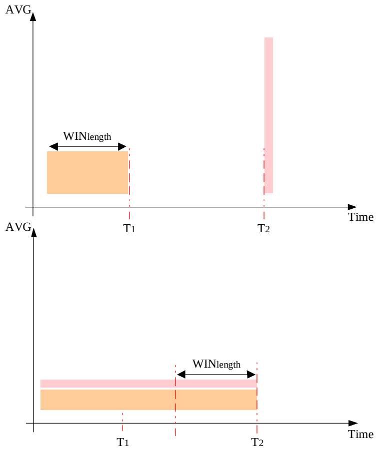
After every packet arrival:

$Bytes_{TSW}=avg(n)\cdot Win_{length}$

$New_{bytes}=Bytes_{TSW}+PacketLength$

$$avg(n+1)=\frac{New_{bytes}}{T_{now}-T_{front}+Win_{leght}}$$

$T_{front}=T_{now}$



Metering

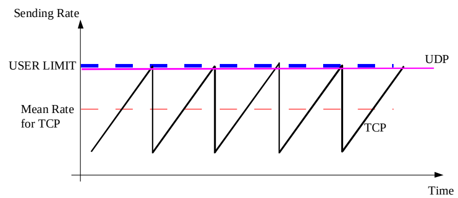
- Based on the measured information a conformance statement is declared
- Conformance is the observation whether the measured variable is within predefined boundaries.
  - Customer has contracted rate of ***X*** bps with variation of ***x*** bps
  - Customer has contract of average rate ***X*** bps and peak of ***Y*** bps. He is allowed to send bursts of ***Z*** kB in peak rate.

Conformance algorithms

- Strict conformance
  - Packets exceeding contracted rate are marked immediately as non−conforming
- TSW conformance
  - Packets exceeding 1.33 times contracted rate are marked as non−conforming
- Probability conformance
  - Packets exceeding contracted rate are marked as non−conforming with increasing probability

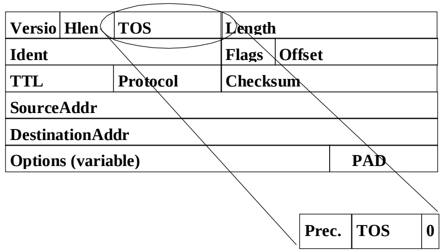
Rate Control Problems

- Two parallel transport protocols with contradicting control:
  - UDP − with no control
  - TCP − with additive increase exponential decrease rate control
- Problem: Metering system cannot easily offer fair service to both TCP and UDP clients in the same system.



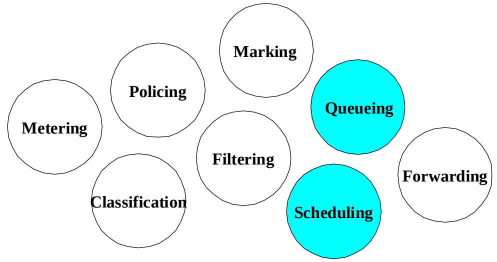
Marking

- Marker is used to attach conformance / class information to every packet.
- Marker uses IPv4 TOS/DSCP field to convey information for other processing elements in the network.
  - TOS
    - Prec: 3 bit priority
    - TOS: user preference for routing
  - DSCP
    - Class and precedence



Output processor

- Output processor of a Internet router consists following elements
  - Queues and their management algorithms
  - Scheduling



Queues

- Queues are used to store **contending** packets
  - Contention is temporary event rising from statistical multiplexing
    - Packets from different input links of a router attempt to the same output link at certain time
    - Packets from a higher speed link arrive temporarily too fast for a slow speed link
- If contention is permanent queues overflow i.e. network is **congested**
- Difference:
  - Contention − packets are not lost only delayed
  - Congestion − packets are not only delayed but also lost

Queues

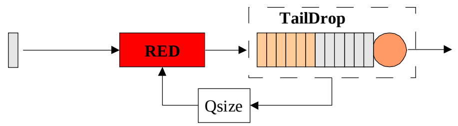
- Congestion situations demand **queue management** to decide
  - When packets should be discarded
  - Which are the packets that should be discarded
- Prevalent solutions
  - Tail Drop
  - Random Early Detection (RED)
  - Random Early Detection In/Out (RIO)

Tail Drop

- Simple algorithm:
  - If arriving packets sees a full queue it is discarded
  - Otherwise it is accepted to the queue
- Problem:
  - Poor fairness in distribution of buffer space
  - Unable to accommodate short transients when queue is almost full
    - Bursty discarding leading global syncronisation
- Global syncronisation is a process where large number of TCP connections syncronise their window control due to concurrent packet losses.
  - Packet losses are bursty, therefore window decreases to one and halts the communication

Random Early Detection

- RED is an active queue management algorithm (AQM), which aims to
  - Prevent global syncronisation
  - Offer better fairness among competing connections
  - Allow transient burst without packet loss
- Algorithm operates on the knowledge of current Qsize
  - Updated on every arrival and departure from the actual queue



RED

- Qsize is used to calculate average length of the queue:

Initial condition:
$avg(0)=0$
$Count=-1$
When Qsize=0:
$T_{idle}=T_{now}$
After every packet arrival:
if $Qsize(n)>0$:
$avg(n+1)=(1-\epsilon)\cdot avg(n)+\epsilon\cdot Qsize(n)$
else:
$avg(n+1)=avg(n)\cdot(1-\epsilon)^{f(T_{now}-T_{idle})}$

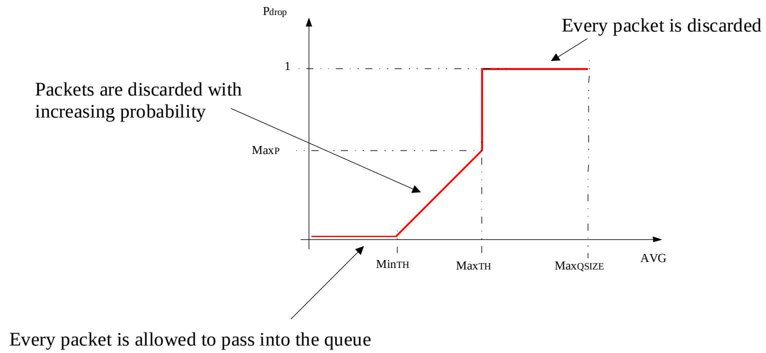
If queue is empty, averaging is done based on the assumption that N packets have passed the algorithm before actual packet arrival. -> Decay of average during idle times

- Packets are discarded based on the average queue length:

if $avg(n+1)<min_{th}$:
$Count=-1$
else if $min_{th}\le avg(n+1)<max_{th}$:
$count=count+1$
$$P_b(n+1)=max_p\cdot\frac{avg(n+1)-min_{th}}{max_{th}-min_{th}}$$
$$P_a(n+1)=\frac{P_b(n+1)}{1-count\cdot P_b(n+1)}$$
With probability $P_a(n+1)$:
Discard packet
$Count=0$
else if $max_{th}\le avg(n+1)$
Discard packet
$Count=0$

Stochastic packet discard

RED

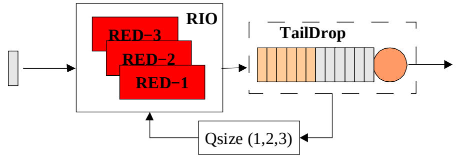


Achievements of RED

- Some packets are discarded even before overflow of the actual buffer
  - Is it good or bad ?
    - Bad: A part of buffer space is in some occasions wasted
    - Good: A signal is sent to co−operating sources that they should decrease their sending rate or congestion will occure
- On the average early packet discards will hit connections which use more than their fair share of capacity in contending link
  - Is it good or bad ?
    - Bad: Makes differentiation impossible
    - Good: Is consistent policy and withing the goal of conventional Best Effort model

RED In/Out − WRED

- When we aim for differentiation of resources we must also allow different shares of resources in contending link or buffer
- One way to do it is to use RED with several parallel algorithms and thresholds
  - RED In/Out −> RIO or WRED
  - Popular implementations use two or three parallel algorithms
- This requires that packets are marked
  - One algorithm is responsible of one or several marks



RIO

- Operation is usually based on following idea:
  - Customer has contracted capacity of X bps
  - He sends packets with rate Y bps
  - If Y is greater than X, some packets are marked as out of profile.
    - Out of profile packets usually experience harsh treatment on contending situations
- Calculation of the average queue length is modified to take into accout number of packets with different markings:
  - In (green): Only green packets
  - In/Out (yellow): Green and yellow packets
  - Out (red): All packets in the queue

Parameters in WRED

- All parameres are independent for different markings
  - More dimensions in creating differentiation
- Some parameters are common for different markings
  - Less dimensions but more understandable