CS 7260 Internet Architectures and Protocols

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Token Bucket Algorithm

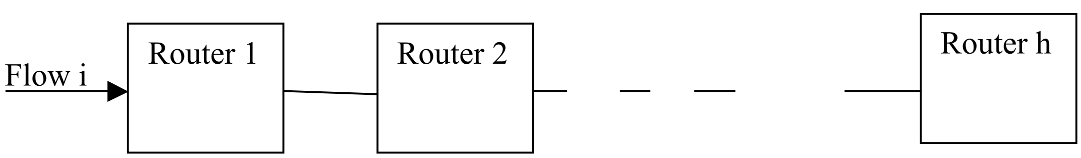
Let
P_i = size of the bucket
r_i = Rate at which the bucket is filled
* The filling rate corresponds to how much the network allows you to transmit in a particular flow.
* The idea is if there are enough tokens in a bucket, packets are transmitted. Tokens are subtracted as packets are transmitted.
* If there are not enough tokens, the packet is held until a certain number 'L' of tokens are available.
* If the bucket is full, it means you cannot accumulate tokens beyond P(i).

This has implications -

* Σr_i <= Total rate of the link, r. In other words, the sum of the rate of individual flows must be lesser than the total transmission rate of the link. This is required for deterministic guarantee.

Theorem on End to End delay guarantee of WFQ -

* Let a flow pass through a set of links -

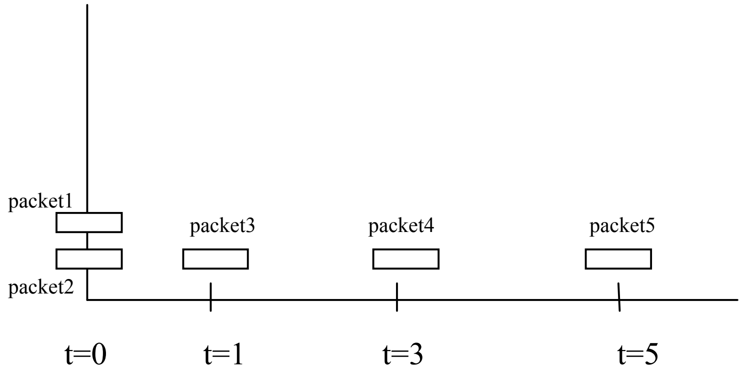


Part 1 -
* For flow 'i' = (P(i),r(i)) through a single router in which WFQ is applied, what is the delay bound of the packets through that router for that flow?

The delay is $P_i/r_i + \Theta_i$

* P_i/r_i is the time taken by a burst of size P(i) to be cleared. P(i) is the maximum size of the burst.

Example -
* If the size of a bucket is 5 bits of tokens, then if each packet uses 2 bits of token, at time t=0, 2 packets will use a total of 4 bits of token. Then 1 bit of token is left. The third packet will not be transmitted until t=1.



$\Theta(i) = L_{max}/r + L_{max(i)}/r_i$

$L_{max(i)}$ = Maximum size of packet inside Flow 'i'.
L_{max} = Maximum size of packet on that link.

$L_{max(i)}/r_i$ = Time taken to transmit maximum sized packet in flow 'i'.

Part2 - When the same flow flows through two links

* The delay over the first link would be $P_i/r_i + \Theta_{i,1}$.

* The delay over the first link would be $P_i/r_i + \Theta_{i,2}$.

* Total delay over 2 links is $P_i/r_i + \Theta_{i,1} + P_i/r_i + \Theta_{i,2}$.

* $\Theta_{i,1}$ and $\Theta_{i,2}$ could be different because there could be multiple flows on a single link. L_{max} could be different on different links. $L_{max(i)}$ could be the same but r_i could be different across links.

* Since P_i/r_i appears twice in the end to end delay equation, the customer of such a network would be paying twice for the same service.

* If the customer does not want to pay twice, the end to end delay equation ought to be $P_i/r_i + \Theta_{i,1} + \Theta_{i,2}$.

* Therefore, by extending the same formula to 'h' links the delay is

$$P_i/r_i + \Sigma(\Theta_{i,j}) \text{ where 'j' ranges from 1 to 'h'}.$$

Note: The leaky bucket rate should always be lesser than the rate of flow 'i'.

* The above proof can be proved using **latency rate framework.**

Latency Rate -

* If 'T' is the time our traffic arrives and 't' is a time greater than 'T', then w(T,t) is the amout of work that can be done between T and t.

* $w(T,t) >= \max\{0, r_i(t - \gamma - \delta_i)\}$

* $r_{i,}$, δ_i is called the **latency rate server**.

Note: 'T' must be the start of a busy period of flow 'i'.