# Lecture – Oct 31st 2012 by Sachit Muckaden

The previous lecture talked about 3 events that occur in a simulation of a GPS that require actions –

1. An inactive flow becomes active.
    - This means that a first-in-session packet arrives.
2. An active flow becomes inactive.
    - This means a last-in-session packet departs under GPS.
3. A non-last-in-session packet departs.

Dealing with these 3 events depends on how fast the processor is. We will assume for simplicity that the processor is infinitely fast. Having an infinitely fast processor implies that we always have enough processing power to handle these events and hence there is no backlog of events to be handled at any time.

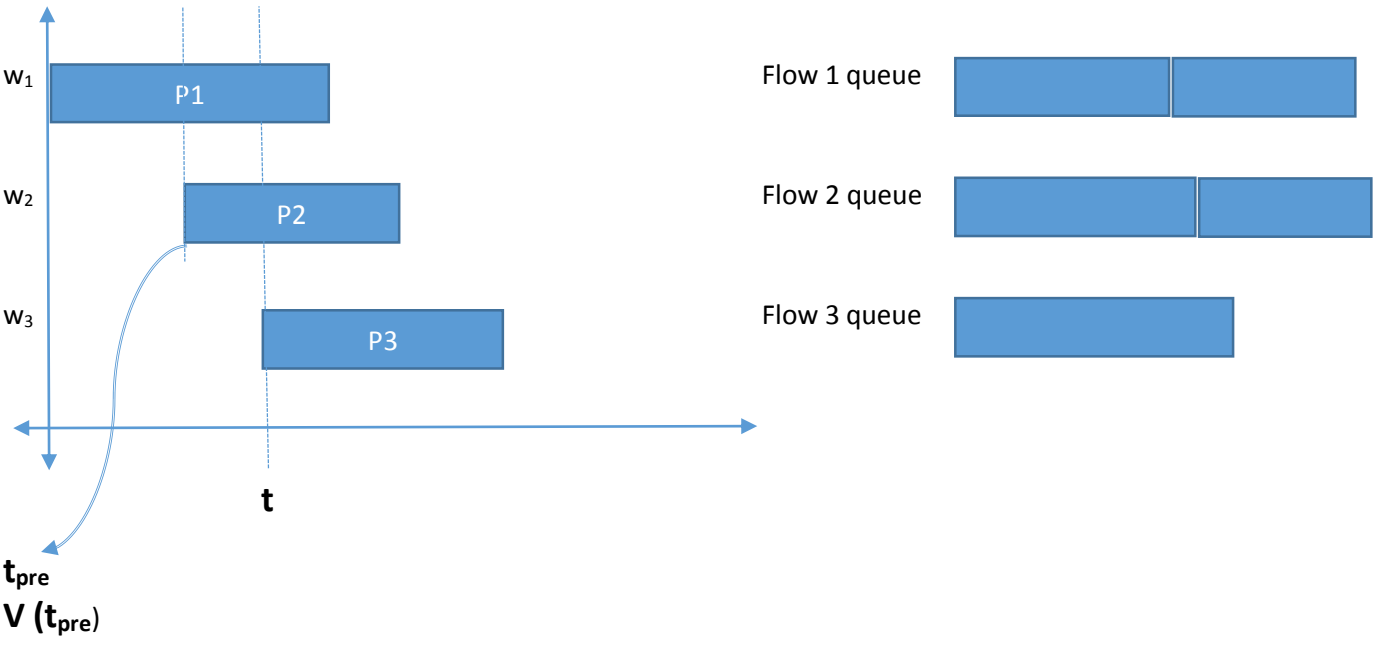
In order for the GPS simulator to function we only consider the head-of-line (HOL) packets. The remaining packets are in their respective per-flow queues. Whenever a HOL packet finishes the next one can move in.

At every moment we have a function V (t) (the virtual time). This function is a piecewise linear function of slope. If each flow has a weight one and there are 3 flows then the slope is 1/3rd.

## Type 1 event –

A type 1 event is referred to as a *rude awakening*.

Consider the following diagram –



In this diagram:

w1, w2 and w3 are the weights of the flows.

$t_{pre}$ and V ($t_{pre}$) are known values of real time and virtual time for the previous event, shown in the figure.

At time t, the following steps are taken.

### Step 1 –

When type 1 event happens at time t, we first need to figure out what is V (t).

When P3 arrives we know the weights of the previous packets as well as the real $t_{pre}$ and virtual time (V ($t_{pre}$)) of arrival.

$$V\ (t) = V\ (tpre) + \frac{t - tpre}{total - weight\ during\ [tpre, t]}$$

We remember the values of t and V (t).

### Step 2 –

Next, we compute the total weight at time t,

$$total - weight\ =\ total - weight\ +\ w3$$

### Step 3 –

Next we compute the virtual finish time of p3 as,

$$V\ (t) + \frac{length\ of\ P3}{w3}$$

We always need to sort the virtual finish time of all the HOL packets. Hence we need a data structure that maintains a priority queue of the GPS virtual finish times of all HOL packets.

Consider an abstract data structure. The requirements are –

1. It needs to be a priority queue
2. It needs to support insert and extract min operations.

We insert the virtual finish time computed above into our data structure.

### Step 4 -

The next job is to figure out the real-time-to-next-event.

The virtual time of the next event is determined from an EXTRACT MIN operation on the data structure. In this case the next event is end of packet P1.

Real-time-to-next-event =

$$[V\ (finish\ time\ of\ P1) -\ V(t)] *\ total - weight$$

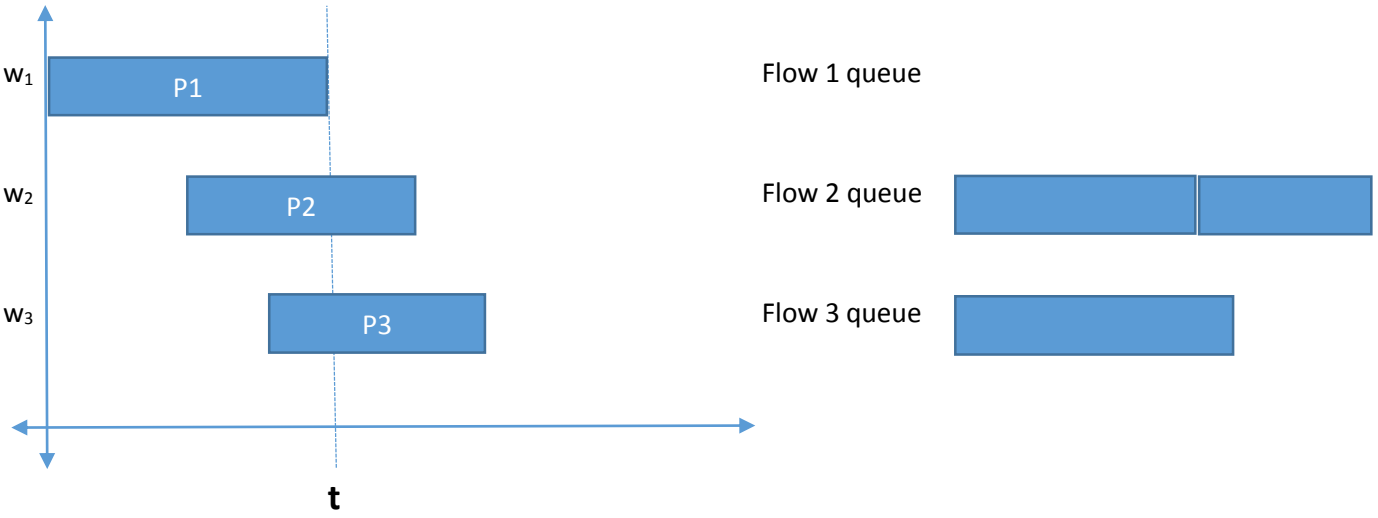
### Step 5 –

The simulator then proceeds to Sleep (real-time-to-next-event) duration or until it is rudely awakened.

A generalized step-by-step review for a type 1 packet –

1. Calculate the virtual time when the packet arrives. Remember both the virtual and real times.
2. Calculate the total-weight.
3. Calculate the virtual finish time of the new packet and insert that into the data structure.
4. Execute extract min operation on the data structure to determine the next event.
5. Real-time-to-next-event = $[V\ (next\ event) - V\ (t)] * total - weight$
6. Sleep until the real-time-to-next-event or until rudely awakened.

## Type 2 event –

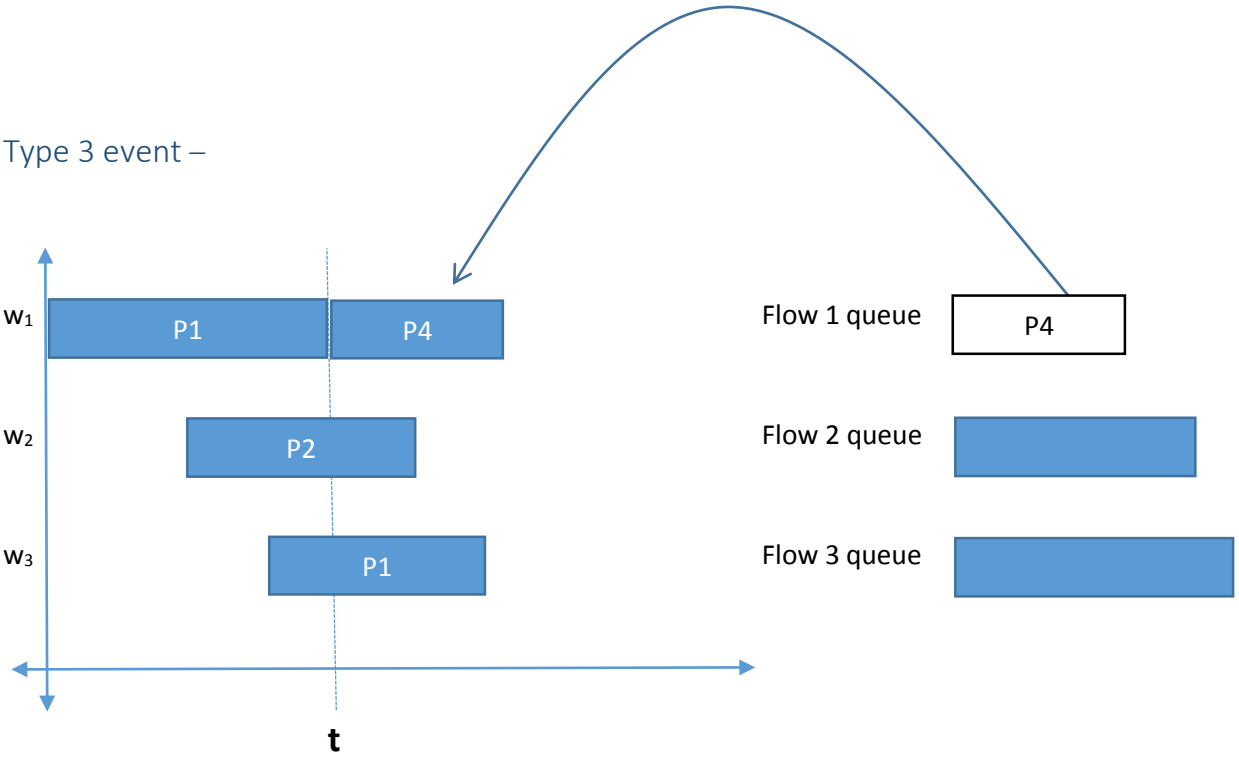



In the above diagram, the flow 1 queue is empty implying that P1 is a last-in-session packet.

The following steps are taken –

1. We already know V (t) and t hence these do not need to be computed.
2. $total - weight\ =\ total - weight - w1$
3. No insertion to the data structure is required because the flow has ended.
4. Virtual time of the next event is determined by the extract min operation on the data structure. real-time-to-next-event is calculated.
5. Simulator sleeps for real-time-to-next-event duration or time rudely awakened.

Type 3 event –




Packet P4 moves over from flow queue after P1 ends.

When type 3 event happens V (t) doesn't change. Hence this type of event is easiest to process.

The following steps are taken –

1. We know t and V (t) when the packet enters hence these do not need to be computed.
2. total-weight remains unchanged.
3. V (finish time) of the packet is calculated and inserted into the priority queue.
4. Virtual time of the next event is determined by the extract min operation on the data structure. real-time-to-next-event is calculated.
5. Simulator sleeps for real-time-to-next-event duration or time rudely awakened.

This is how the GPS simulator deals with the 3 different types of events. The scheduler makes calls to the GPS simulator which returns the appropriate packet based on the priority queue.