Dead Time Calculation Assignment

In this take-home examination problem you will need to

- Construct an accurate dead time simulation for a semi-realistic readout
- Determine the minimum buffer length required to keep dead time below 1%.

Description of the system:

The system you will simulate is a simplified model of the ATLAS LAr calorimeter readout. The parameters you will use are as follows:

1. **Bunch crossing rate: 40 MHz**. For the purposes of this exercise, assume that all bunch crossings are filled, and have an equal chance of producing an event. The actual bunch structure for LHC is more complex, with trains of bunches (nominally 72 at 25 ns spacing) separated by gaps with different lengths.
2. **L1 accept (L1A) rate: 75 kHz.** Again, assume that the probability of producing a trigger is the same for all bunch crossings, and equal to 75 kHz/40 MHz.
3. **5 BX minimum time between L1 triggers:** In current running conditions, the LAr system reads out data from five consecutive bunch crossings for each event. Due to constraints in the front-end electronics, the trigger is blocked from issuing an L1A for the four bunch crossings following a previous L1A. This is part of the ATLAS dead time.
4. **Readout time: 10.6 µs.** This corresponds to 424 bunch crossings, and is the time necessary to read out five bunch crossings worth of calorimeter data. For the purposes of this exercise, assume that an event is available for readout from the fifth bunch crossing after the L1A that produced it.

Producing a Monte Carlo simulation of the system:

You may write the simulation in any language or design environment that you feel comfortable with. A suggested approach is to use a model where each consecutive bunch crossing has a random chance to produce a L1A. If the L1A is too soon after a previous one (see point 3 above), the event is blocked. Otherwise the event is added to a "leaky bucket" model of the derandomizing buffer, which empties at a constant rate.

For this assignment, the *buffer size* is defined as the number of events being held for readout. The buffer size is incremented by one for each new L1A accepted, and decremented by one after each event is fully read out. If an L1A arrives while the buffer size is already at a maximum, the event is blocked from being read out.

Dead time calculation:

Define the *buffer length* as the maximum buffer size allowed by the hardware. Given the above parameters, calculate the dead time of the system for different buffer lengths. This is the percentage of bunch crossings where a L1A is blocked, and is the combined result of the minimum L1A spacing and buffer-full conditions described above.

Assignment and report:

Using your simulation, determine the minimum buffer length L_{MIN} needed to keep total dead time below 1%. Write and submit a short report describing your work, and with a results section that includes:

1) Your result for the minimum buffer length L_{MIN} (in number of events)
2) Calculated dead times (in percent) for L_{MIN}, and for cases (L_{MIN} - 1) and (L_{MIN} + 1).

Complete and email your report to silver@physto.se by Friday, November 16. You may also feel free to contact me with any questions.