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 in Run 1. Use the following parameters:

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 bunches per train with 25 ns intervals) separated by gaps with varying lengths.
2. **Level-1 accept (L1A) rate: 75 kHz.** Again, assume that the probability of producing an L1A is the same for any bunch crossing. That probability would equal to 75 kHz/40 MHz.
3. **5 BX minimum time between L1 triggers:** When an L1A is received, the LAr system reads out data from five consecutive bunch crossings. Since the LAr electronics cannot read out overlapping events, the trigger is blocked from issuing a new L1A for the next four bunch crossings after a previous L1A. This contributes to the ATLAS dead time.
4. **Readout time: 10.6 µs.** This corresponds to 424 bunch crossings, and is the time needed to read out five bunch crossings of data off the detector with the available bandwidth. For the purposes of this exercise, assume that the data for a triggered event arrives at the derandomizing buffer five bunch crossings (125 ns) after the L1A that produced it.

Building a Monte Carlo simulation of the system:

You may write the simulation in any language or design environment that you are comfortable with. Use a model where each consecutive bunch crossing has a random chance to produce a L1A. If an L1A is issued too soon after a previous one (see point 3 above), the event is blocked (adding to dead time). 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 in the derandomizing buffer at a given time, awaiting readout. The buffer size increases by one for each new L1A accepted, and decreased by one after each event is fully read out (see point 4 above). If an L1A arrives while the buffer size is already at a maximum, a "busy" condition occurs, and the event is blocked from being read out (again, adding to dead time).

Dead time calculation:

Dead time is the percentage of time that an L1A does not result in an event being read out. If *buffer length* is defined as the maximum buffer size accommodated in the hardware, use your simulation to estimate the dead time for different buffer lengths.

Assignment and report:

Determine the minimum buffer length L_{MIN} required to keep total dead time below 1%. Write a short report describing your work, including a results section containing (at least):

1) The minimum buffer length L_{MIN} (in number of events) to produce <1% dead time.
2) The dead time percentage at L_{MIN}, as well as for (L_{MIN} - 1) and (L_{MIN} + 1).

Complete and email your report to silver@fysik.su.se by Friday, November 27. You may also feel free to contact me with any questions.