Verilog Scheduling and Event Queue

Consider

```
always_ff @( posedge clk ) c = reset ? 0 : c + 1;
always_ff @( posedge clk ) over_th = c + 1'd1 > threshold;
```

Is `over_th` computed using the new or old `c`?

(Answer: either one, and so code is unreliable.)

Terminology

Event:

Sort of a to-do item for simulator. May include running a bit of Verilog code or updating an object's value.

Event Queue:

Sort of a to-do list for simulator. It is divided into time slots and time slot regions.

Time Slot:

A section of the event queue in which all events have the same time stamp.

Time Slot Region:

A subdivision of a time slot. There are many of these. Important ones: active, inactive, NBA.

Scheduling:

Determining when an event should execute. The when consists of a time slot and a time slot region.

Update Events:

The changing of an object's value. Will cause *sensitive* objects to be scheduled.

Time Slot Regions

Rationale:

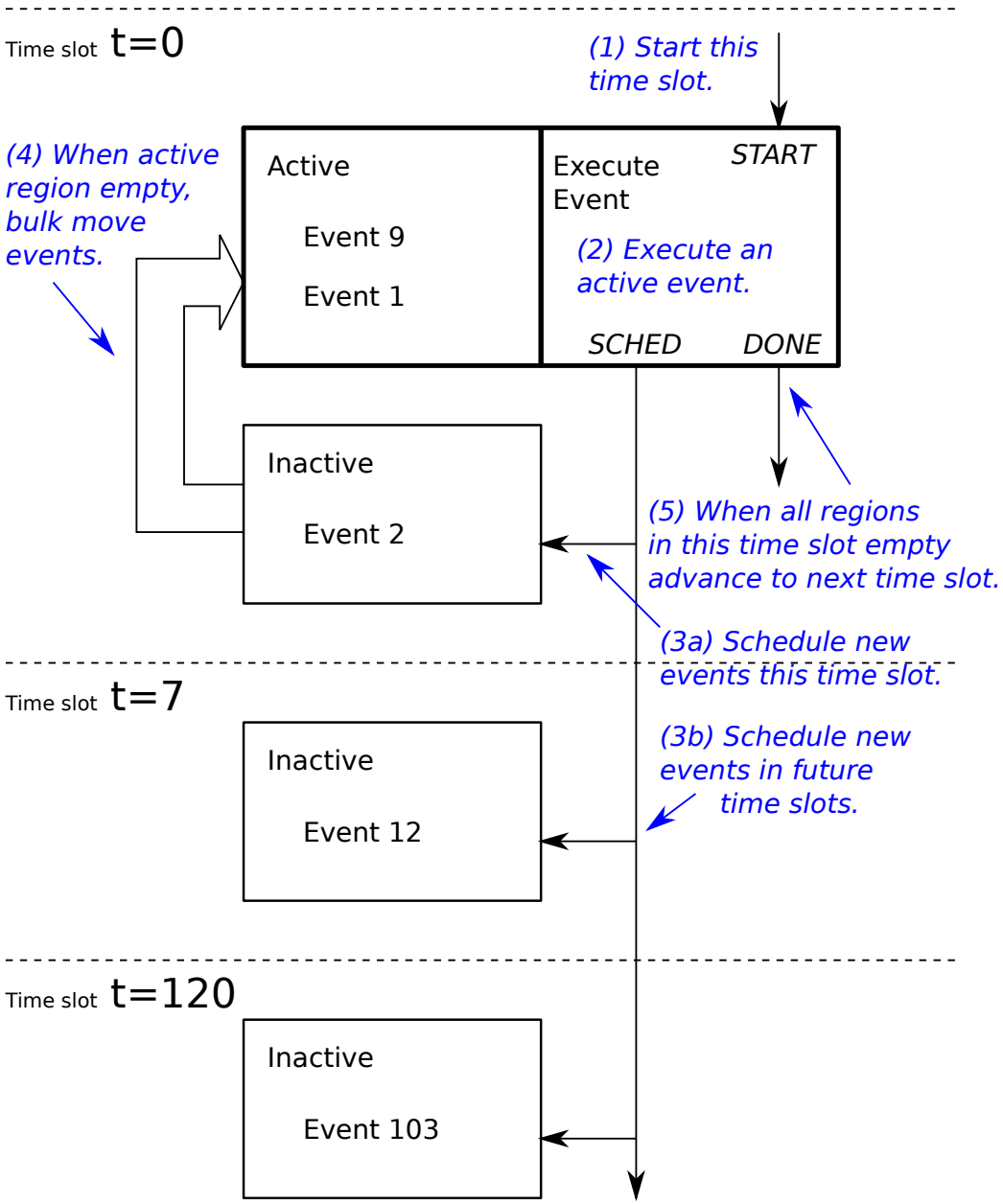
"Do it now!" is too vague. Need to prioritize.

SystemVerilog divides a time slot into 17 *regions*.

Some Regions

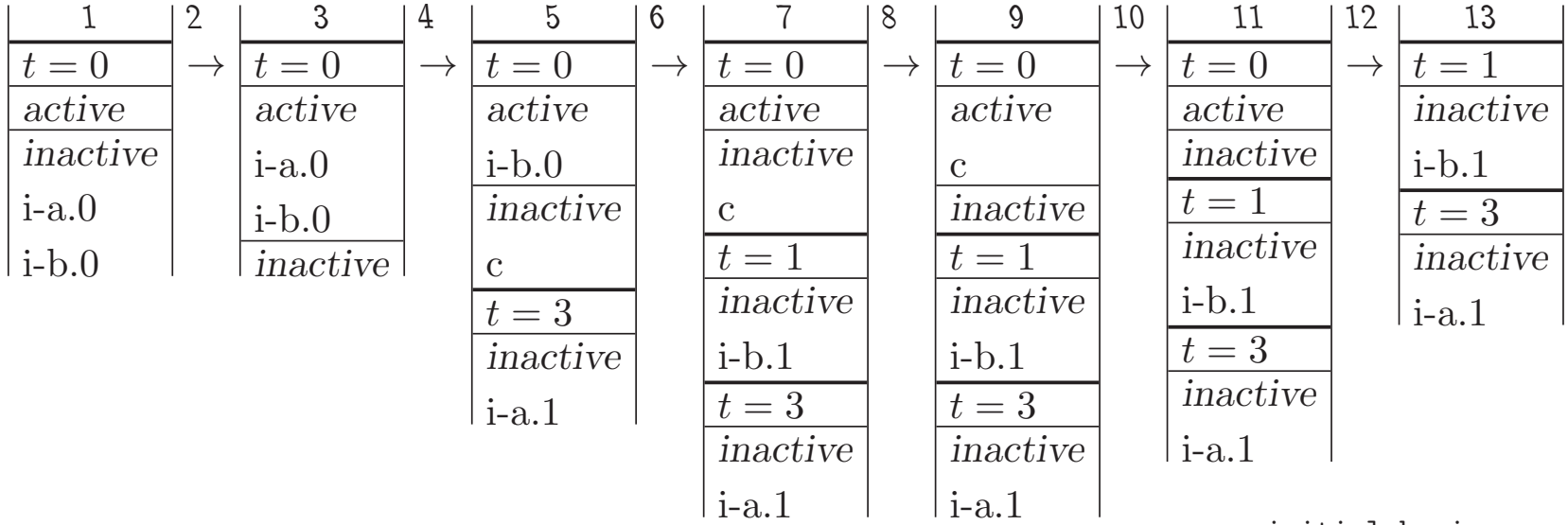
Active Region:
Events that the simulator is currently working on. Only the current time slot has this region.

Inactive Region:
Contains normally scheduled events. Current and future time slots have this region.


Time slot t=0
(1) Start this time slot.
(4) When active region empty, bulk move events.
Active
Event 9
Event 1
Execute Event
START
(2) Execute an active event.
SCHED
DONE
Inactive
Event 2
(5) When all regions in this time slot empty advance to next time slot.
(3a) Schedule new events this time slot.
Time slot t=7
Inactive
Event 12
(3b) Schedule new events in future time slots.
Time slot t=120
Inactive
Event 103

eq-4

Event Queue Example



1: Verilog puts all `initial` blocks in $t = 0$'s inactive region.

2: Active region is empty, and so inactive copied to active.

3: Event `i-a.0` executes and schedules event `c` for $t = 0$ ...
... and `i-a.1` for $t = 3$.

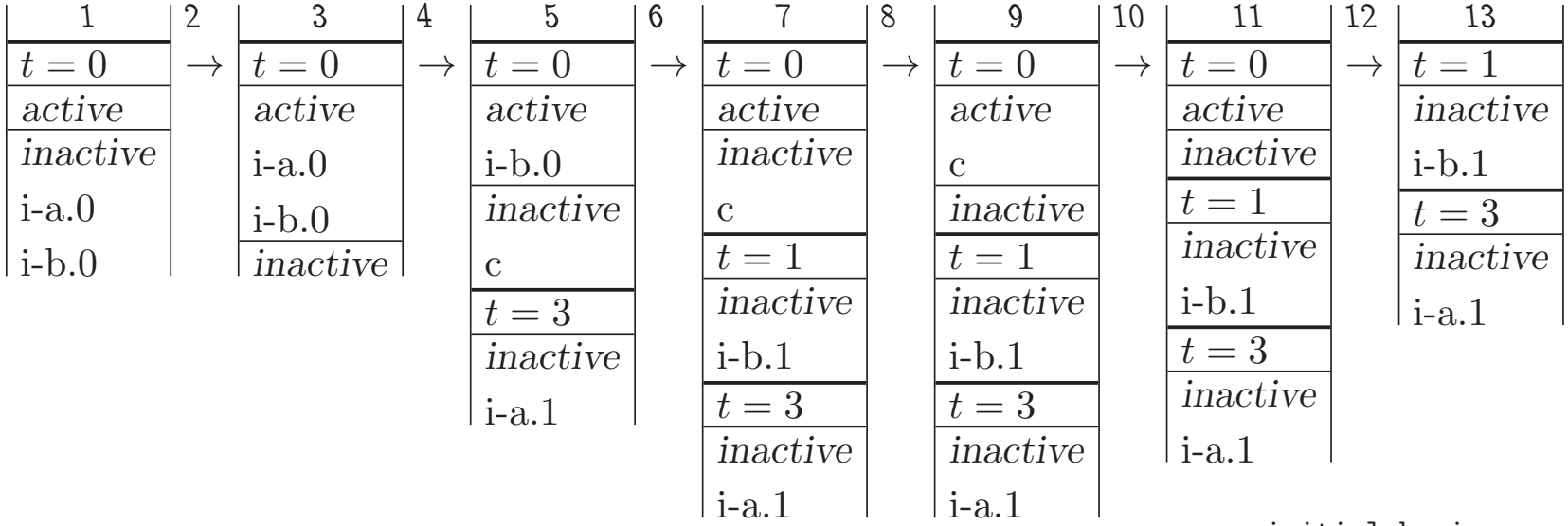
4: Event `i-a.0` removed from active region (it is now not scheduled anywhere).

```
initial begin
   // i-a.0
   a = 1;
   #3;
   // i-a.1
   a = 2;
end

initial begin
   // i-b.0
   b = 10;
   #1;
   // i-b.1
   b = a;
end

assign c = a + b;  // c
```

Event Queue Example



5,6: Event `i-b.0` executes and schedules `i-b.1` for $t = 1$.

7,8: Since active region is empty, inactive region is bulk-copied to active region.

9: Event `c` executes.

10-12: Since all regions in time slot 0 are empty, move to next time slot, $t = 1$.

```
initial begin
   // i-a.0
   a = 1;
   #3;
   // i-a.1
   a = 2;
end

initial begin
   // i-b.0
   b = 10;
   #1;
   // i-b.1
   b = a;
end

assign c = a + b;  // c
```

Some More Regions

NBA Region:

Update events from non-blocking assignments.

Postponed Region:

Events scheduled using `$watch` system task.

Event Scheduling

Time-Delay Scheduled

Scheduled by a delay: `#4 a = b;`

Put in inactive region of a future time step.

Sensitivity List Scheduled

Explicit event: `@( a )`, `@( posedge clk )`, `wait( stop_raining )`

Continuous assignment: `assign x = a + b;`.

Module or primitive ports: `and myAndGate(x,a,b)` .

Put in inactive region of current time step.

Update Events

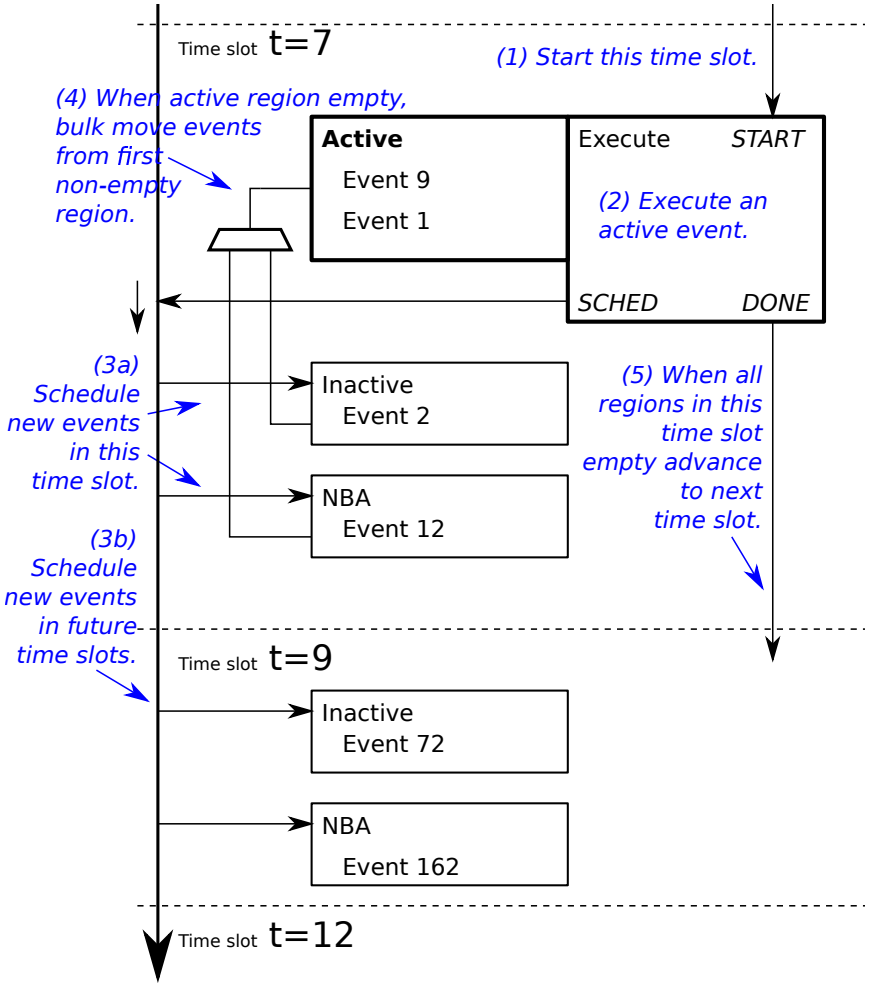
Non-blocking assignment: `y <= a + b;`.

Put in NBA region of current time step.

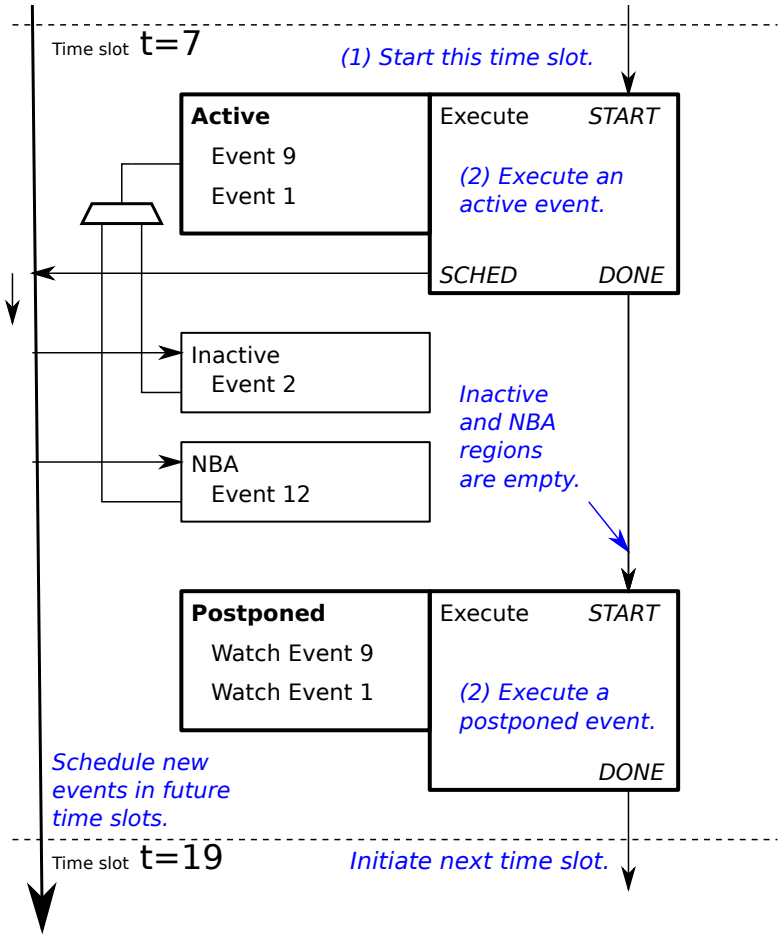
Permanently Scheduled

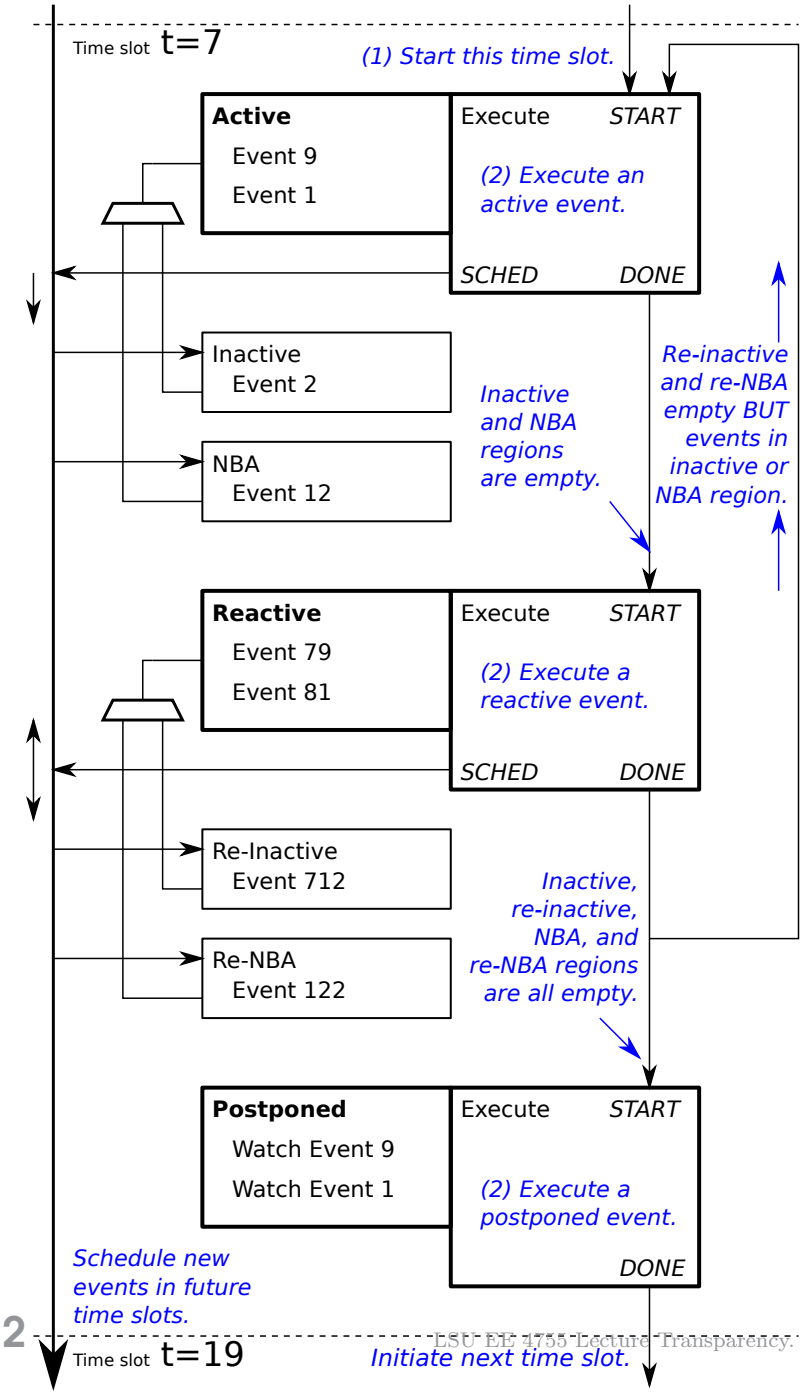
Watch lists: `$watch(a)`.

Put in postponed region of every time step.


Time slot t=7
(1) Start this time slot.
(4) When active region empty, bulk move events from first non-empty region.
Active
Event 9
Event 1
Execute START
(2) Execute an active event.
SCHED DONE
(3a) Schedule new events in this time slot.
Inactive
Event 2
NBA
Event 12
(5) When all regions in this time slot empty advance to next time slot.
(3b) Schedule new events in future time slots.
Time slot t=9
Inactive
Event 72
NBA
Event 162
Time slot t=12

eq-10


Time slot t=7
(1) Start this time slot.
Active
Event 9
Event 1
Execute START
(2) Execute an active event.
SCHED DONE
Inactive
Event 2
NBA
Event 12
Inactive and NBA regions are empty.
Postponed
Watch Event 9
Watch Event 1
Execute START
(2) Execute a postponed event.
DONE
Schedule new events in future time slots.
Time slot t=19
Initiate next time slot.


Time slot t=7
(1) Start this time slot.
Active
Event 9
Event 1
Execute START
(2) Execute an active event.
SCHED DONE
Inactive
Event 2
NBA
Event 12
Inactive and NBA regions are empty.
Re-inactive and re-NBA empty BUT events in inactive or NBA region.
Reactive
Event 79
Event 81
Execute START
(2) Execute a reactive event.
SCHED DONE
Re-Inactive
Event 712
Re-NBA
Event 122
Inactive, re-inactive, NBA, and re-NBA regions are all empty.
Postponed
Watch Event 9
Watch Event 1
Execute START
(2) Execute a postponed event.
DONE
Schedule new events in future time slots.
Time slot t=19
Initiate next time slot.