MODULE *4state*

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EXTENDS *Integers*, *FiniteSets*
CONSTANT N
ASSUME $N \in Nat \setminus \{0, 1\}$
$Procs \triangleq 1 \,..\, (N-1)$ Or $0 \,..\, N$ should J be equal to procs or not?

$Numberize(S) \triangleq$ IF $S =$ TRUE THEN 1 ELSE 0

Dijkstra's 4 state

```
--algorithm 4state{
    variable up = [i ∈ 0 .. N ↦ Numberize(i = 0)], c = [i ∈ 0 .. N ↦ 0] ;
      variable up = [i ∈ 0 .. N ↦ Numberize((i%2) = 0)], c = [i ∈ 0 .. N ↦ (i%2)];
   fair process ( i ∈ {0} )
   {   I0: up[self] := 1 ;
       I1: while ( TRUE )
             { await ((c[0] = c[1]) ∧ up[1] = 0) ;
               c[0] := (c[0] + 1)%2 ;
             }
    }
   fair process ( n ∈ {N} )
   {
       N0: up[self] := 0 ;
       N1: while ( TRUE )
             { await (c[(N − 1)] ≠ c[N]) ;
               c[N] := c[(N − 1)] ;
             }
    }
   fair process ( j ∈ Procs )
   {
        J1: while ( TRUE )
        {
             either
                { await (c[self] ≠ c[(self − 1)]) ;
                    c[self] := c[(self − 1)] ;
                    up[self] := 1 ;
                }
             or
                { await ((c[(self)] = c[(self + 1)]) ∧ up[(self + 1)] = 0 ∧ up[self] = 1) ;
                    up[self] := 0 ;
                }
         }
```

```
   }
}
```

BEGIN TRANSLATION

VARIABLES $up,\ c,\ pc$

$vars \triangleq \langle up,\ c,\ pc \rangle$

$ProcSet \triangleq (\{0\}) \cup (\{N\}) \cup (Procs)$

$Init \triangleq$ Global variables
$\land\ up = [i \in 0\ ..\ N \mapsto Numberize(i = 0)]$
$\land\ c = [i \in 0\ ..\ N \mapsto 0]$
$\land\ pc = [self \in ProcSet \mapsto \text{CASE } self \in \{0\} \rightarrow \text{“I0”}$
$\square\ self \in \{N\} \rightarrow \text{“N0”}$
$\square\ self \in Procs \rightarrow \text{“J1”}]$

$I0(self) \triangleq \land\ pc[self] = \text{“I0”}$
$\land\ up' = [up \text{ EXCEPT } ![self] = 1]$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“I1”}]$
$\land\ c' = c$

$I1(self) \triangleq \land\ pc[self] = \text{“I1”}$
$\land\ ((c[0] = c[1]) \land up[1] = 0)$
$\land\ c' = [c \text{ EXCEPT } ![0] = (c[0] + 1)\%2]$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“I1”}]$
$\land\ up' = up$

$i(self) \triangleq I0(self) \lor I1(self)$

$N0(self) \triangleq \land\ pc[self] = \text{“N0”}$
$\land\ up' = [up \text{ EXCEPT } ![self] = 0]$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“N1”}]$
$\land\ c' = c$

$N1(self) \triangleq \land\ pc[self] = \text{“N1”}$
$\land\ (c[(N-1)] \neq c[N])$
$\land\ c' = [c \text{ EXCEPT } ![N] = c[(N-1)]]$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“N1”}]$
$\land\ up' = up$

$n(self) \triangleq N0(self) \lor N1(self)$

$J1(self) \triangleq \land\ pc[self] = \text{“J1”}$
$\land\ \lor\ \land\ (c[self] \neq c[(self-1)])$
$\land\ c' = [c \text{ EXCEPT } ![self] = c[(self-1)]]$
$\land\ up' = [up \text{ EXCEPT } ![self] = 1]$
$\lor\ \land\ ((c[(self)] = c[(self+1)]) \land up[(self+1)] = 0 \land up[self] = 1)$

$$\begin{array}{l} \land\ up' = [up \text{ EXCEPT } ![self] = 0] \\ \land\ c' = c \\ \land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“J1”}] \end{array}$$

$j(self) \triangleq J1(self)$

$$\begin{array}{ll} Next \triangleq & (\exists\, self \in \{0\} : i(self)) \\ & \lor (\exists\, self \in \{N\} : n(self)) \\ & \lor (\exists\, self \in Procs : j(self)) \end{array}$$

$$\begin{array}{ll} Spec \triangleq & \land\ Init \land \Box[Next]_{vars} \\ & \land\ \forall\, self \in \{0\} : \mathrm{WF}_{vars}(i(self)) \\ & \land\ \forall\, self \in \{N\} : \mathrm{WF}_{vars}(n(self)) \\ & \land\ \forall\, self \in Procs : \mathrm{WF}_{vars}(j(self)) \end{array}$$

END TRANSLATION

$T\_0 \triangleq \text{IF } ((c[0] = c[1]) \land (up[1] = 0)) \text{ THEN } 1 \text{ ELSE } 0$
$T\_N \triangleq \text{IF } c[N] \neq c[N-1] \text{ THEN } 1 \text{ ELSE } 0$
$T \triangleq Cardinality(\{k \in Procs : (c[k] \neq c[k-1]) \lor ((c[k] = c[k+1]) \land (up[k] = 1) \land (up[k+1] = 0))\}) + T\_0 -$
$Invariant \triangleq T = 1$
$Stabilization \triangleq \Box\Diamond Invariant$
$LowerBound \triangleq T \geq 1$
$DoesNotMoveAway \triangleq \Box[T' \leq T]_{vars}$
$MovesTowards \triangleq \forall\, M \in 1 \,..\, N+1 : \Box\Diamond(T \leq M)$

* Modification History
* Last modified Sun *Dec* 13 01:56:07 *EST* 2015 by *chartoin*
* Created *Fri Dec* 11 19:03:34 *EST* 2015 by charuvah