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Operating Systems

Internals and Design Principles

Ninth Edition
2018

*Readers/Writers Problem,
Ver. 6*

```
$ cat -n rdr_wrt_msg_v6.pml | expand
```

```
1  #define NRDRS      5
2  #define NWRTS      2
3  #define MAXRDRS    100
4  #define MAXRDRQ    20
5  #define MAXWRRQ    20
6
7  chan readrequest   = [MAXRDRQ] of { byte }
8  chan writerequest = [MAXWRRQ] of { byte }
9  chan finished      = [MAXRDRQ+MAXWRRQ] of { byte }
10 chan mbox[NRDRS+NWRTS+1] = [MAXRDRQ+MAXWRRQ] of { bool }
11
12 int count = MAXRDRS
13 mtype = { reader, writer }
14 byte nr = 0, nw = 0
15
```

...

...

```
16  proctype ReaderWriter(byte i; mtype who) {
17      chan ch
18      if
19      :: who == reader -> ch = readrequest
20      :: else -> ch = writerequest
21      fi
22
23      ch ! i                                // send request
24      atomic {
25          mbox[i] ? _                      // receive ok to access
26          printf("%e %d\n",who,i)
27      }
```

...

```
...
28      if                                // inc counter
29      :: who == reader -> nr++
30      :: else -> nw++
31      fi
32      assert(nw < 2)
33      assert((nw > 0 && nr == 0) || (nw == 0 && nr > 0))
34      atomic {
35          if                                // dec counter
36          :: who == reader -> nr--
37          :: else -> nw--
38          fi
39          finished ! i                    // send to finished
40      }
41  }
42
...
```

...

```
43  proctype Controller() {
44      byte r,w      // process id
45
46      do
47          :: count > 0 ->    // readers are working
48  end:    if
49          :: nempty(finished) ->
50              atomic {
51                  finished ? r
52                  printf("finished Reader %d\n",r)
53              }
54              count++
55          :: empty(finished) && nempty(writerequest) ->
56              atomic {
57                  writerequest ? w
58                  printf("request from Writer %d\n",w)
59              }
60              count = count - 100      // no more readers
```

...

...

```
61      :: empty(finished) && empty(writerequest) && nempty(readrequest) ->
62          atomic {
63              readrequest ? r
64              printf("request from Reader %d\n",r)
65          }
66          count--
67          atomic {
68              mbox[r] ! true // send ok to reader
69              printf("OK to Reader %d\n",r)
70          }
71      fi
72      :: count == 0 -> // there aren't readers
73          atomic {
74              mbox[w] ! true // send ok to writer
75              printf("OK to Writer %d\n",w)
76          }
77          atomic {
78              finished ? w // wait writer finishing
79              printf("finished Writer %d\n",w)
80          }
81          count = 100
```

```
...
82      :: count < 0 -> // writer is waiting because reader's
access
83          atomic {
84              finished ? r
85              printf("finished Reader %d\n",r)
86          }
87      count++
88  od
89 }
90
...
```

...

```
91  init {
92      byte i
93
94      atomic {
95          for (i : 1 .. NRDRS+NWRTS) { /* R1,R2,W3,R4,W5,R6,R7 */
96              if
97                  :: i == 3 || i == 5 ->
98                      run ReaderWriter(i,writer)
99                  :: else ->
100                      run ReaderWriter(i,reader)
101              fi
102          }
103      run Controller()
104  }
105 }
```


Random execution (1/4)

```
$ spin rdr_wrt_msg_v6.pml
```

```
request from Writer 5  
OK to Writer 5
```

```
writer 5
```

```
finished Writer 5  
request from Writer 3  
OK to Writer 3
```

```
writer 3
```

```
finished Writer 3  
request from Reader 7  
OK to Reader 7
```

```
reader 7
```

```
request from Reader 4  
OK to Reader 4
```

```
reader 4
```

```
finished Reader 7  
finished Reader 4
```

```
...
```

Random execution (2/4)

...

request from Reader 2
OK to Reader 2

reader 2

request from Reader 1
OK to Reader 1

reader 1

request from Reader 6
OK to Reader 6

reader 6

finished Reader 2
finished Reader 1
finished Reader 6

timeout

...

Random execution (3/4)

```
...  
#processes: 9  
queue 3 (readrequest):  
queue 1 (writerequest):  
queue 2 (finished):  
queue 4 (mbox[0]):  
queue 5 (mbox[1]):  
queue 6 (mbox[2]):  
queue 7 (mbox[3]):  
queue 8 (mbox[4]):  
queue 9 (mbox[5]):  
queue 10 (mbox[6]):  
queue 11 (mbox[7]):  
count = 100  
nr = 0  
nw = 0  
...
```

Random execution (4/4)

...

```
240:   proc  8 (Controller:1) rdr_wrt_msg_v6.pml:48 (state 20) <valid end state>
240:   proc  7 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  6 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  5 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  4 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  3 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  2 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  1 (ReaderWriter:1) rdr_wrt_msg_v6.pml:41 (state 27) <valid end state>
240:   proc  0 (:init::1) rdr_wrt_msg_v6.pml:105 (state 17) <valid end state>
```

9 processes created

Verification: too much time (1/3)

```
$ spin -run rdr_wrt_msg_v6.pml | expand
```

Depth=	166	States=	1e+06	Transitions=	3.37e+06	Memory=	617.011	t=	2.76	R=	4e+05
Depth=	166	States=	2e+06	Transitions=	6.46e+06	Memory=	1105.292	t=	5.3	R=	4e+05
Depth=	166	States=	3e+06	Transitions=	9.57e+06	Memory=	1593.573	t=	7.82	R=	4e+05
Depth=	166	States=	4e+06	Transitions=	1.31e+07	Memory=	2081.855	t=	10.6	R=	4e+05
Depth=	166	States=	5e+06	Transitions=	1.65e+07	Memory=	2570.136	t=	13.5	R=	4e+05
Depth=	166	States=	6e+06	Transitions=	2e+07	Memory=	3058.417	t=	16.4	R=	4e+05
Depth=	166	States=	7e+06	Transitions=	2.41e+07	Memory=	3546.698	t=	19.7	R=	4e+05
Depth=	166	States=	8e+06	Transitions=	2.78e+07	Memory=	4034.980	t=	22.8	R=	4e+05
Depth=	166	States=	9e+06	Transitions=	3.09e+07	Memory=	4523.261	t=	33.1	R=	3e+05
Depth=	166	States=	1e+07	Transitions=	3.45e+07	Memory=	5011.542	t=	41.4	R=	2e+05
Depth=	166	States=	1.1e+07	Transitions=	3.84e+07	Memory=	5499.823	t=	50.5	R=	2e+05
Depth=	166	States=	1.2e+07	Transitions=	4.25e+07	Memory=	5988.105	t=	60	R=	2e+05
Depth=	166	States=	1.3e+07	Transitions=	4.66e+07	Memory=	6476.386	t=	94.6	R=	1e+05
Depth=	166	States=	1.4e+07	Transitions=	5.09e+07	Memory=	6964.667	t=	122	R=	1e+05
Depth=	166	States=	1.5e+07	Transitions=	5.52e+07	Memory=	7452.948	t=	169	R=	9e+04
Depth=	166	States=	1.6e+07	Transitions=	5.9e+07	Memory=	7941.230	t=	193	R=	8e+04
Depth=	166	States=	1.7e+07	Transitions=	6.33e+07	Memory=	8429.511	t=	216	R=	8e+04
Depth=	166	States=	1.8e+07	Transitions=	6.74e+07	Memory=	8917.792	t=	253	R=	7e+04
Depth=	166	States=	1.9e+07	Transitions=	7.14e+07	Memory=	9406.073	t=	295	R=	6e+04
Depth=	166	States=	2e+07	Transitions=	7.42e+07	Memory=	9894.355	t=	331	R=	6e+04
Depth=	166	States=	2.1e+07	Transitions=	7.72e+07	Memory=	10382.636	t=	386	R=	5e+04
Depth=	166	States=	2.2e+07	Transitions=	7.99e+07	Memory=	10870.917	t=	431	R=	5e+04
Depth=	166	States=	2.3e+07	Transitions=	8.28e+07	Memory=	11359.198	t=	475	R=	5e+04
Depth=	166	States=	2.4e+07	Transitions=	8.62e+07	Memory=	11847.480	t=	506	R=	5e+04
Depth=	166	States=	2.5e+07	Transitions=	8.96e+07	Memory=	12335.761	t=	522	R=	5e+04
Depth=	166	States=	2.6e+07	Transitions=	9.25e+07	Memory=	12824.042	t=	713	R=	4e+04
Depth=	166	States=	2.7e+07	Transitions=	9.54e+07	Memory=	13312.323	t=	4.25e+03	R=	6e+03

...

Verification: too much time (2/3)

```
...
Depth=      166 States=  2.8e+07 Transitions= 9.86e+07 Memory= 13800.605      t= 6.47e+03 R=   4e+03
Depth=      166 States=  2.9e+07 Transitions= 1.02e+08 Memory= 14288.886      t=  9.5e+03 R=   3e+03
Depth=      166 States=   3e+07 Transitions= 1.05e+08 Memory= 14777.167      t= 1.36e+04 R=   2e+03
```

^CInterrupted

(Spin Version 6.4.8 -- 2 March 2018)

Warning: **Search not completed**

+ Partial Order Reduction

Full statespace search for:

```
never claim          - (none specified)
assertion violations  +
cycle checks          - (disabled by -DSAFETY)
invalid end states    +
```

State-vector 576 byte, depth reached 166, errors: 0

30302155 states, stored

75955938 states, matched

1.0625809e+08 transitions (= stored+matched)

10295239 atomic steps

hash conflicts: 35567118 (resolved)

...

Verification: too much time (3/3)

...

Stats on memory usage (in Megabytes):

17454.626	equivalent memory usage for states (stored*(State-vector + overhead))
14796.182	actual memory usage for states (compression: 84.77%)
	state-vector as stored = 484 byte + 28 byte overhead
128.000	memory used for hash table (-w24)
0.534	memory used for DFS stack (-m10000)
14924.628	total actual memory usage

pan: elapsed time 1.49e+04 seconds = **248.33 minutes = 4.14 hours**

pan: rate 2035.6745 states/second