

Slot-queue - An optimized wait-free distributed MPSC

1. Motivation

A good example of a wait-free MPSC has been presented in [1]. In this paper, the authors propose a novel tree-structure and a min-timestamp scheme that allow both enqueue and dequeue to be wait-free and always complete in $\Theta(\log n)$ where n is the number of enqueueers.

We have tried to port this algorithm to distributed context using MPI. The most problematic issue was that the original algorithm uses load-link/store-conditional (LL/SC). To adapt to MPI, we have to propose some modification to the original algorithm to make it use only compare-and-swap (CAS). Even though the resulting algorithm pretty much preserve the original algorithm's characteristic, that is wait-freedom and time complexity of $\Theta(\log n)$, we have to be aware that this is $\Theta(\log n)$ remote operations (and in reality, there are about $5 * \log n$ remote operations), which is very expensive.

Therefore, to be more suitable for distributed context, we propose a new algorithm that's inspired by LTQueue, in which both enqueue and dequeue only perform a constant number of remote operations, at the cost of dequeue having to perform $\Theta(n)$ local operations, where n is the number of enqueueers. Because remote operations are much more expensive, this might be a worthy tradeoff.

2. Structure

Each enqueue will have a local SPSC as in LTQueue [1] that supports dequeue, enqueue and readFront. There's a global queue whose entries store the minimum timestamp of the corresponding enqueueer's local SPSC.



Figure 1: Basic structure of slot queue

3. Pseudocode

3.1. SPSC

The SPSC of [1] is kept in tact, except that we change it into a circular buffer implementation.

Types

```

data_t = The type of data stored
spsc_t = The type of the local SPSC

record
    First: int
    Last: int
    Capacity: int
    Data: an array of data_t of capacity
    Capacity
end

```

Shared variables

```

First: index of the first undequeued entry
Last: index of the first unenqueued entry

```

Initialization

```

First = Last = 0
Set Capacity and allocate array.

```

The procedures are given as follows.

Procedure 1: `spsc_enqueue(v: data_t)` **returns** `bool`

```

1 if (Last + 1 == First)
2   | return false
3 Data[Last] = v
4 Last = (Last + 1) % Capacity
5 return true

```

Procedure 2: `spsc_dequeue()` **returns** `data_t`

```

6 if (First == Last) return  $\perp$ 
7 res = Data[First]
8 First = (First + 1) % Capacity
9 return res

```

Procedure 3: `spsc_readFront` **returns** `data_t`

```

10 if (First == Last)
11   | return  $\perp$ 
12 return Data[First]

```

3.2. Slot-queue

The slot-queue types and structures are given as follows:

Types

data_t = The type of data stored
 timestamp_t = uint64_t
 spsc_t = The type of the local SPSC

Shared variables

slots: An array of timestamp_t with the number of entries equal the number of enqueueers
 spscs: An array of spsc_t with the number of entries equal the number of enqueueers
 counter: uint64_t

Initialization

| Init all local SPSCs.

| Init slots entries to MAX.

The enqueue operations are given as follows:

Procedure 4: `enqueue(rank: int, v: data_t)` **returns** `bool`

```

1 timestamp = FFA(counter)
2 value = (v, timestamp)
3 res = spsc_enqueue(spsc_s[rank], value)
4 if (!res) return false
5 propagateEnqueue(rank, timestamp)
6 return res

```

Procedure 5: `propagateEnqueue(rank: int, ts: timestamp_t)`

```

7 old-timestamp = slots[rank]
8 front = spsc_readFront(spsc_s[rank])
9 new-timestamp = front ==  $\perp$  ? MAX : front.timestamp
10 CAS(&slots[rank], old-timestamp, new-timestamp)

```

The dequeue operations are given as follows:

Procedure 6: `dequeue()` **returns** `data_t`

```

11 rank = readMinimumRank()
12 if (rank == DUMMY || slots[rank] == MAX)
13   | return  $\perp$ 
14 res = spsc_dequeue(spsc_s[rank])
15 if res ==  $\perp$  return  $\perp$ 
16 propagateDequeue(rank)
17 return res

```

queues and stacks,” 2005, *Springer-Verlag*. doi:
10.1007/11590156_33.

Procedure 7: readMinimumRank() returns int

```

18 rank = length(slots)
19 min-timestamp = MAX
20 for index in 0..length(slots)
21   timestamp = slots[index]
22   if min-timestamp < timestamp
23     rank = index
24     min-timestamp = timestamp
25 old-rank = rank
26 for index in 0..old-rank
27   timestamp = slots[index]
28   if min-timestamp < timestamp
29     rank = index
30     min-timestamp = timestamp
31 return rank == length(slots) ? DUMMY :
   rank

```

Procedure 8: propagateDequeue(rank: int)

```

32 old-timestamp = slots[rank]
33 front = spsc_readFront(spsc[rank])
34 new-timestamp = front ==  $\perp$  ? MAX :
   front.timestamp
35 if (front !=  $\perp$ )
36   slots[rank] = new-timestamp
37 return
38 CAS(&slots[rank], old-timestamp, new-
   timestamp)

```

4. Linearizability

5. Wait-freedom

6. Memory-safety

References

- [1] P. Jayanti and S. Petrovic, “Logarithmic-time single deleter, multiple inserter wait-free