CSE 4/586: Project 1

Murat Demirbas

[2016-10-27 Thu]

1 Replicated Storage with Client-Side Routing

There are *N=5* storage nodes and a client that is writing to the storage nodes. At most *FAILNUM* number of storage nodes can fail, and failed nodes can recover anytime with their storage intact. In order to ensure persistence, the client writes to a subset of the up nodes, denoted as the write quorum (*WriteQ*). In order to ensure consistency of the writes, before performing the write the client reads from a subset of the up nodes, denoted as the read quorum (*ReadQ*), and learns the highest versioned write completed, increments the version number, and performs the write to the *WriteQ* nodes.

This protocol corresponds to DynamoDB and Voldemort key-value storage protocols with some simplifications.

For simplicity we assume the client keeps writing to only one item, so we ignore modeling of the key part of the key-value pair item, and hashing of the key to the storage system to figure out which nodes form the *WriteQ* and *ReadQ*. Our *WriteQ* and *ReadQ* selection will consist of the lowest id storage nodes that are up (currently not failed).

1.1 Write a PlusCal program to represent this algorithm.

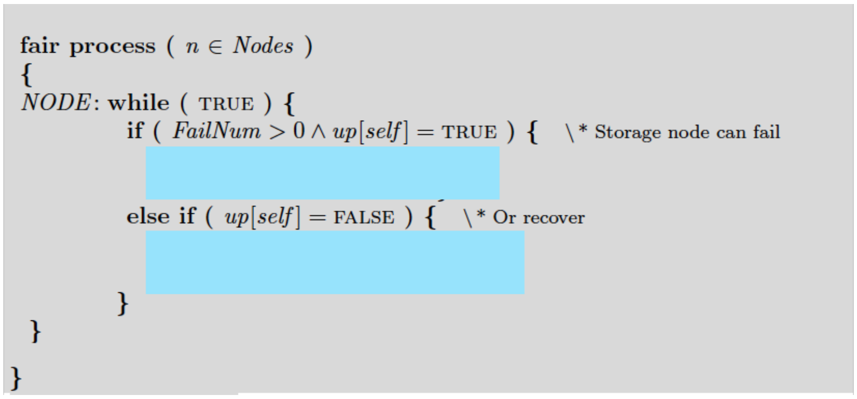
Use the below template as your starting point, and fill in the redacted parts. Use the toolkit to translate your code to TLA+ and model-check for correctness.

```
MODULE volfinal
Replicated storage protocol with clientside routing
EXTENDS $Integers$, $Sequences$, $FiniteSets$, $TLC$
CONSTANTS $N$, $C$, $STOP$, $ReadQ$, $WriteQ$, $FAILNUM$
ASSUME $N = 5 \land C = 1 \land STOP < 10 \land 1 \leq ReadQ \land ReadQ \leq 3$
           $\land 1 \leq WriteQ \land WriteQ \leq 3 \land 0 \leq FAILNUM \land FAILNUM \leq 2$
$Nodes \triangleq 1 \,..\, N$
$Clients \triangleq N + 1 \,..\, N + C$   \* should give different $ID$ space to Client

--algorithm voldemort
{
  variable $FailNum = FAILNUM$,
           $up = [n \in Nodes \mapsto \text{TRUE}]$,   \*Initially all nodes are up
           $db = [n \in Nodes \mapsto \{[ver \mapsto 0, val \mapsto 0]\}]$;
           \* All nodes have database, wherein $[ver = 0, val = 0]$ stored for the item

  define
  {
   [redacted]
   $UpNodes \triangleq \{$[redacted]
   $ReturnReadQ \triangleq$ [redacted]
   $ReturnWriteQ \triangleq$ CHOOSE $i \in$ SUBSET $(UpNodes) : Cardinality(i) = WriteQ$
     \* CHOOSE deterministically returns lowest $ID$ nodes that satisfy the requirement
  }

  fair process ( $c \in Clients$ )
  variable $cntr = 0$, $hver = 0$, $Q = \{\}$;
  {
   CL: while ( $cntr \leq STOP$ ) {
         $cntr := cntr + 1$;
         \* get the highest version number from read Quorum
         [redacted]
         \* write $val = cntr$ to $writeQuorum$ with higher version number
     [redacted]
         }
  }
```



```
fair process ( $n \in Nodes$ )
{
NODE: while ( TRUE ) {
            if ( $FailNum > 0 \land up[self] = \text{TRUE}$ ) {   \* Storage node can fail

            else if ( $up[self] = \text{FALSE}$ ) {   \* Or recover

            }
 }
}
```

1.2 Model-check safety properties with TLA+

- Write an invariant to capture the single-copy consistency property of the storage protocol. Single-copy consistency means the *N=5* storage nodes appear to outside as if it is a single virtual unfailable node, even though upto *FAILNUM* of physical storage nodes can fail. More specifically, the highest version number result returned by a read from *ReadQ* of storage nodes should match the item stored by the most recent write operation on the system.

  - We have a single client of the storage system, and for the sake of simplicity it only implements writes to the system. But you can still check for single-copy consistency is satisfied without having to implement the read operation. You can also use a simplified/shortcut check for the single-copy consistency leveraging the way the client stores items to the storage system.
  - Single-copy consistency property should be satisfied when *FAILNUM=0*, i.e., when no node is allowed to fail. The property will fail to be satisfied for certain combinations *ReadQ* & *WriteQ* when *FAILNUM>0*.

- Write in the comments section, after the "================" line, your findings/observations about the relation between *ReadQ*, *WriteQ*, and *FAILNUM* that ensures the protocol satisfies the single-copy consistency property.

2 Submission

Your TLA+ file should be named *voldemort.tla* . Your model's name should be the default name *Model*_1 (do not name your model file differently).

Generate a pdf print of your TLA+ program using the "Produce Pdf version" from the TLA+ menu. (This will get included in your submission as it is created under the ".toolbox" directory.)

Now create a zip file from the ".tla" file and the corresponding ".toolbox" directory. **Name the zipfile as: proj1.zip**

Not following these directions will cause you to lose points.

You will use the submit command (*submit*_*cse*486 or *submit*_*cse*586 respectively) to submit your work. The submit command instructions are here: `https://wiki.cse.buffalo.edu/services/content/submit-script`