HW1 Solutions: CS425 FA18

1. (Solution and Grading by: <Le Xu>)

1st Mapper/Reducer

Map1 (key, value) // where key follows value

```
{
        Emit<key, value>
}
```

Reduce1 (key, list)

```
{
        if list.length >= 3
            For i from 0 to list.length
                For j from i to list.length
                    For k from j to list.length
                          Emit(sort(key, list[i], list[j], list[k]), key)
}
```

2nd Mapper/Reducer

Map2 (key, value) // key in the form of <k1, k2, k3, k4>, value in the form of a key

```
{
          Emit<key, value>
}
```

```
Reduce2 (key, list) // key in the form of <k1, k2, k3, k4>, value in the form of a list
{
        If list.length == 4 Emit <key, list>

}
```

2. (Solution and Grading by: <Shegufta>)

1st Mapper/Reducer

```
Map1 (key, value) // input (a, b) where a follows b
{
        if( b == @packers )
                emit ( @packers,  a)
        else
                emit ( sort(a,b), “” ) // the function sort(x,y) sorts “x” and “y” lexicographically
                                       // this ensures identical “key” for both (x,y) and (y,x)
}
```

```
Reduce1(key, value)
{
        List L = value.getList();

        If(key == @packers) // “L” contains followers of @packers…. e.g. “L” == <p,q,r>
        {
                For each “unique” pair (a,b) in “L”
                        emit (sort(a,b), 1);
                        //hints: unique pairs in this example are <(p,q), (p,r), (q,r)>
        }
        Else
        {
                emit (key, 0) // note that, “key” is the lexicographically sorted list of a and b
                              // here, “at least” one of them follows the other
        }
}
```

2nd Mapper/Reducer

```
Map2(key, value) // "key" is the sorted usernames (from Reduce 1), value is either 0 or 1
{
        emit(key, value)
}

Reduce2(key, value)
{
        List L = value.getList();
        length = L.getLength();

        if( 1 == length && 1 == value)
        {
                // (1 == length) ensures that the key was emitted from a single "source"
                // (1 == value) ensures that the "source" is the @packer's follower list

                a = split(key)[0]; // get the first user from the lexicographically sorted list
                b = split(key)[1]; // get the second user from the lexicographically sorted list

                emit(a, b);
        }
}
```

3. (Solution and Grading by: <Beomyeol>)

1st Mapper/Reducer

```
map (k, v) {  // v is an input line formatted (a, b) when a follows b.
  Parse an input line v = (a, b)  // a follows b
  output (a, (b, ∅))
  output (b, (∅, a))
}
```

```
reduce (k, V) {
  followingSet ← ∅
  followerSet ← ∅
  foreach v = (a, b) ∈ V do
    followingSet ← followingSet ∪ {a}
    followerSet ← followerSet ∪ {b}
  end
  if @KingJames ∈ followingSet then
    output (k, #)  // k follows @KingJames
  else if k != @KingJames ∧ |followerSet| > 10M then
```

```
    foreach u ∈ followerSet do
      output (u, *)  // u follows k s.t. k is not @KingJames, doesn't follow @KingJames, and has over 10M followers
    done
  end
}
```

2nd Mapper/Reducer

map (*k*, *v*) { // *k,v is an output of 1st Reducer above. k is username. v is either* (true, false) or (false, true)
  output (k, v)
}

reduce (*k*, *V*) {
  if * ∈ *V* ∧ # ∈ *V* **then**
    output *k*
  end
}

4. (Solution and Grading by: Rui)
    a. M=2k+1. The design could tolerate 2k simultaneous failures.
    Consider a scenario where a certain process P is never selected into the random-k subset by any other process. P would only need to send heartbeat to its k predecessors and k successors. If these 2k processes fail simultaneously, the failure of P would not be detected by any active processes. Thus, this design does not provide completeness for 2k+1 simultaneous failures (2k + process P). When there are only 2k simultaneous failures, there is always at least one process alive among 2k neighbours, so the failure of P will always be detected.
    b. No.
    Heartbeat protocols are never 100% accurate in an asynchronous system as heartbeats can be lost.
    c. Worst case: (N-1) heartbeats per second. Every process except for P itself chooses P to send heartbeat.
    Best case: 2k heartbeats per second. Only the k predecessors and k successors of P choose P to send heartbeat (required).
    Average case: 3k per second. Every process would ask 3k processes to send heartbeat, thus there are 3k * N heartbeats sent per period(second) in total. On

average, it is (3k * N) / N = 3k heartbeats per second.

5. (Solution and Grading by: Rui)
   a. The protocol is eventually complete. A faulty member will be eventually chosen as a ping target at every non-faulty member, so it will be considered as faulty eventually .
   b. The probability of a process P is pinged every period is $1-(1-\frac{m}{N})^{N-1}$. The ping happens every T time units. Thus, the expected detection time is $T/(1-(1-\frac{m}{N})^{N-1})$.
      $\lim_{N\to\infty} T/(1 -\times (1-\frac{m}{N})^{N-1}) = T/(1-e^{-m})$.
   c. Thus, The expected detection time is still independent of N if N is large enough.

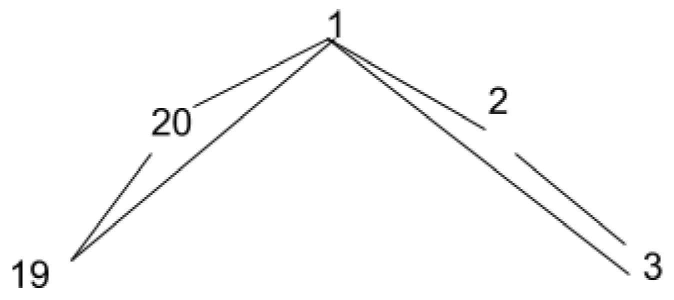
6. (Solution and Grading by: Zhuolun)
   Consider any node in the system. The probability it is chosen with full membership list is B/N. The probability it is chosen with partial membership list is m/k*k/N=m/N. When they are equal, B=m.

7. (Solution and Grading by: Faria)
   a. The memory cost is the cost of storing the finger table. Although we have altered the algorithm used to populate the finger table, we have not added any more entries and so the size of the finger table should remain the same as that in the original algorithm = O(log N).
   b. Again, the lookup cost is similar to the cost of Chord, as all the algorithm needs to work is the existence of any one finger in the range n+2^i and n+2^(i+1). By choosing a neighbor that is closest in terms of latency in the given interval, we achieve the same effect as Pastry does with its locality principle.
   c. Original TA answer: initial i means smaller values of i → There are fewer choices in the initial hops as the value of i is small. Therefore, the algorithm makes bigs jumps in the initial hops and smaller jumps later, where larger values of i lead to more choices amongst neighbors.
      However, a lot of students have taken initial hops to mean initial hops *while routing*, when i would be bigger. There, initial hops would be smaller as there are more choices and later hops would be bigger.
      Both answers are accepted (if the correct explanation is provided).

General comments:

1. Most students have failed to provide a comparison between earlier and later jumps.
2. Some students have presented an answer without an explanation. In this case, they will lose all points.

8. (Solution and Grading by: Rahul)



a.
There are 20 nodes in the system, let's say we start at node 1.
Step 1 :
TTL = 3
19,20,1,2,3
Step 2:
TTL = 2
17,18,19,20,1,2,3,4,5
Step 3:
TTL = 1
15,16,17,18,19,20,1,2,3,4,5,6,7
Therefore **13 nodes** receive the query message.

b. A **minimum TTL = 5** is required for all nodes to receive the message.
Step 1 :
TTL = 5
19,20,1,2,3
Step 2:
TTL = 4
17,18,19,20,1,2,3,4,5
Step 3:
TTL = 3

15,16,17,18,19,20,1,2,3,4,5,6,7

Step 4:

TTL = 2

13,14,15,16,17,18,19,20,1,2,3,4,5,6,7,8,9

Step 5:

TTL = 1

11,12,13,14,15,16,17,18,19,20,1,2,3,4,5,6,7,8,9,10

c. Let Node 21(coach) be connected to all the nodes
If Node 1 is sending the message it is connected to 21, so 21 receives the message and transmits it to every other node in 2 TTL
For **TTL = 2** we can be sure that all the nodes receive the query.

9. (Solution and Grading by: <Beomyeol>)

a.

i	*f[i]*	*i*	*f[i]*
0	2020	6	1992
1	2020	7	1992
2	2020	8	1992
3	2024	9	1992
4	1992	10	1992
5	1992	11	1992

b. 2016 → 1992 → 1996 → 2000

c. 2004, 2012, 2016

10. (Solution and Grading by: Faria)

We modify the reduce function to maintain partial results per key and update them as new values arrive for a given key.

The barrier in the shuffle ensures that all values per key have arrived and are fully sorted before they are passed on to the reduce phase. This is why the reducer expects a list of values per key. If we break the barrier, we would be passing on records to the reducer as soon as they arrive from the mapper. This implies that the reducer must be modified to 1) expect a <key, value> pair as input (instead of <key, list of values> pair), and 2) maintain partial results per key and update the partial results as new values arrive for the given key. Partial results can be stored in any data structure. The developer would now have to specify how partial results should be updated per key as new values arrive. Note that the final result will be exactly as the same as original Hadoop.