CSE 6117 Distributed Computing Assignment 1

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01-13-2016

1 State a necessary and sufficient condition on the graph G for the problem to be solvable

In order for this problem to be solvable, each node (representing an island) is connected to another node *iff* they are at most 30 km apart. There's also a further condition that every node is reachable via some path from any other node in the graph G. Further, let us impose a restriction to make the problem easier to solve: the graph is *complete*. Note that an alternative topology; one that has a central 'master' node within a distance of 30 km to every other 'slave' node would work too. In this alternative topology, each of the 'slave' nodes need not be connected (hence a distance of 30 km). However, we will assume a *complete graph* in this problem.

1. edge(i,k) and $d_{ik} \leq 30$
2. $\forall i \forall k$, $i \neq k$, $path(i,k)$

Where i,k are nodes in graph G. Hence, with these two conditions, we can deduce that that each general has a communication path to any of the other generals each on their own island.

2 Show your condition is sufficient

If the condition stated above is met, then we can solve this problem based on a few assumptions before we begin to design this algorithm.

Assumptions

1. The sender of the message knows it has been received by the receiver (no acknowledgement is necessary).
   (a) If the sender 'sees' that the firework did not fire properly, he will reattempt by using another firework.
   (b) In the case of total communication failure where all fireworks fail to fire, all generals agree to attack at a default time set by the algorithm.

2.1 Algorithm Design

We will use a *commander* and a *lieutenant* type of algorithm, where one of the n nodes is designated as the *commander* and the remaining n-1 nodes are designated as *lieutenant*. We will first layout the foundation of the algorithm then show that it satisfies the following two properties.

- Agreement: In every execution of the algorithm, the generals' decisions must always be identical.
- Validity : If all the generals start with the same preference and there are no communication failures, then their decision should match their common initial preference.

Message Encoding can be done in a number of different ways. Assume that a morse code type of method is used to encode the signal and that each algorithm knows how to decode it. Each of the messages will have a format like so:

1. general origin ID
2. Type : commander/lieutenant
3. time preference
4. Attack (only the commander can set this, initially set to false)

Begin There are two algorithms used by the generals, the first *commander* algorithm is used by the commander, and the second Algorithm *lieutenant* is used by the remaining generals. The algorithm begins with the lieutenants remaining idle until a signal from the commander is received. Initially each of the generals have a preference for when to attack. First, Algorithm *commander* sends out a message with: 1) general ID, 2) Type: (commander/lieutenant), 3) time preference 4) Attack: false. All the nodes receive this message, and if they do not, the sender knows this (note the assumption made earlier) and sends another signal. Each of the general ID's are unique since they know the geography of their archipelago.

Send Message begins with the commander. Since all the watches are synchronized, the commander first checks if it's time preference is $\geq$ current time on his watch. If this is true, he sends a message. In the case of a communication failure and the situation where at least one message gets through before 5 pm when all the algorithms decide to attack at a default time, the commander attempts to resend his time preference after ensuring that his time preference $\geq$ current time. If there is a continuous communication failure, commander stops sending a message after 5 pm and defaults to the 6 pm attack time.

Received message by the other nodes that are connected to the sender node in the Graph G (within 30km) will first check the incoming message's time preference against it's own. If it is different, the receiver will update his time preference to match the incoming message's time preference. If no message has been received by 5 pm (or any arbitrary default time agreed upon by the algorithm), then all nodes in the graph will choose to attack at 6 pm.

Response by lieutenant generals need not be given since there is no acknowledgement (in order to prevent the two generals problem from arising). Instead, note that the assumption was made that the sender knows that his firework was successfully lit and that conditions are favourable such that his neighbouring nodes can see the signal.

Commander and Lieutenants attack knowing that the signal from the commander has been received by each of the generals. If the signal was unable to be sent, there is a fallback where they all agree to attack at a default time, governed by the algorithm.

Correctness is clear if there are no communication failures occurring. Recall this is a key assumption that must be held in order for there to be a valid solution. Let's consider a few cases below.

Case 1 *Initial time preferences are the same, no communication failure.*
Then to satisfy the validity property if the commander sends out a message indicating his time preference and all the lieutenants receive this time preference, all the nodes will have the same time preference. Hence the agreement property is also held in such an execution.

Case 2 *Initial time preferences are different, no communication failure* By the lieutenant algorithms, they will change their time preferences to match that of the commander upon successfully receiving it. Once this process is complete, it reduces down to Case 1, hence the same logic applies.

Case 3 *Initial time preferences are the same, communication failure* In this case, each of the algorithms do not know what the time preference of the other algorithm is, hence it is better to decide on a default case in order to prevent any violation of the validity property from occurring. We design each of the algorithms such that if no signal has been received by a set time (say 5 pm) then we decide to attack at a later time (say 6 pm to give the armies a little time to prepare). Also, note that the commander will cease to continue to attempt to signal after 5 pm even if miraculously he is able to get a clear signal. We have shown that the decisions are the same and that the validity property in such an execution is held.

Case 4 *Initial time preferences are different, communication failure.* Case 4 to each of the algorithms is identical to Case 3 since they do not know the initial time preferences are the same or different. Hence, each lieutenant will wait until 5 pm, and when no signal has been received, will default to the agreed upon time to attack of 6 pm.

2.2 Pseudocode

```
sentMessage = false;                                                    Result: Suc
while attack = false do
    if sentMessage = false then
        send message : [ID: myID, TYPE: commander, Time: myTime, Attack: false];
        sentMessage = true;
    end
    while sentMessage = false and myTimePreference ≥ myClockTime do
        myAttackTime = default time (6 pm);
    end
end
```

Algorithm 1: Algorithm Commander

```
messageReceived = false;
while attack = false do
    if messageReceived = false and myClockTime  default time (5 pm) then
        m
    yAttackTime = default time (6 pm);
    if detected message.TYPE = commander AND detected message.Attack = false then
        if detected message.Time not = myTimePreference then
            messageReceived = true;
            myTimePreference = detected message.Time;
        else if detected message.Time = myTimePreference then
            messageReceived = true;
        end
end
Result: Successful coordination of attack
```

Algorithm 2: Algorithm Lieutenant

3 Show your condition is necessary

The solution to this is trivial; consider a graph wherein some pair of nodes is not reachable, i.e. there is no path between them. Hence there is no way for the commander and lieutenants to communicate and coordinate a specific time to attack. Alternatively, consider a case where each node is only connected to at most two other nodes. In this case, each node is reachable from any other node, but the graph is not complete. In such a situation, we may have a communication failure halfway through, while the first few nodes do indeed get a signal telling them to attack at a certain time. In such a situation, we would violate the agreement property since it is possible that the time preferences are different.