# Distributed System Part 2 Bonus

Daniel Gstoehl

November 20, 2017

## 1 Question

You are asked to design a sensor network to monitor whether air pollution in a city has crossed a critical threshold. You decide to use sensor nodes that are each equipped with a wireless communication module and a single sensor that reports whether pollution has crossed the threshhold or not. All sensors can communicate with each other and should agree on whether pollution has crossed the threshold or not.

### 1.1

During development, you notice that the wireless modules are not entirely reliable. They can spontaneously fail, permanently removing a node from the network. Name or describe a protocol the sensors can use to reach consensus in this scenario.

### 1.2

After some tests you determine that within any given year, 25% of the active sensor nodes will experience a communication failure. After how many years will your network be unable to reach consensus? (You can state the result in whole years).

### 1.3

You also notice that the sensors can fail as well. When a sensor fails, it will output random values but will otherwise behave normally. This makes it impossible to detect a failed sensor. Name or describe a protocol that can reach consensus in this scenario. Assume that there are no other faults or failures.

### 1.4

You determine that 10% of the correctly operating sensors will fail within any given year. Again, calculate after how many years the network will fail to reach consensus (assuming only sensor failures occur).

### 1.5

After informing management about these issues, they agree to increase the project's funding. The funds are sufficient to fix either the wireless modules or the sensors. Upgrading the wireless modules will cost 2 CHF per device, upgrading the sensors will cost 1 CHF per device. You want to choose the most cost-effective (i.e. least cost/year) solution. Which one should you choose?

## 2 Solution

There are multiple possible solutions depending on the algorithms chosen.

### 2.1

They can use Ben-Or randomized consensus as long as more than half the nodes are operational.

### 2.2

3 years.

$$\frac{3}{4} \qquad \text{Ratio of nodes left after 1 year} \tag{1}$$

$$\frac{3}{4} * \frac{3}{4} = \frac{9}{16} \qquad \text{Ratio of nodes left after 2 years} \tag{2}$$

$$\frac{3}{4} * \frac{9}{16} = \frac{27}{64} < \frac{1}{2} \qquad \text{Ratio of nodes left after 3 years} \tag{3}$$

### 2.3

The PBFT algorithm can be used as long as less than a third of the nodes fails.

## 2.4

4 years

$$
\begin{aligned}
&0,9 && \text{Ratio of correct nodes after 1 year} && (4)\\
0,9 * 0.9 =&0.81 && \text{Ratio of correct nodes after 2 years} && (5)\\
0,81 * 0.9 =&0.729 && \text{Ratio of correct nodes after 3 years} && (6)\\
0,729 * 0.9 =&0.6561 < \frac{2}{3} && \text{Ratio of correct nodes after 4 years} && (7)
\end{aligned}
$$

## 2.5

Fixing the sensors is more cost-effective. Fixing the wireless modules will allow the network to operate fault-free for 3 years at a cost of 0.66 CHF per year per node. Fixing the sensors will allow the network to operate for only 2 years but will only cost 0.50 CHF per year per node.