

## ECE 6970: Solutions to Real-Time Systems Homework 5

(1) Each clock can be made to think of itself as the median clock in the system by the two faulty clocks positioning themselves appropriately. For example, to the fastest nonfaulty clock, the two faulty clocks could appear as faster than itself, thereby making it the middle clock. In such a case, each clock would take itself as a reference and not make any changes to its own phase. Over time, the different drift rates of the clocks would cause the time they tell to diverge.

(2) The main difference in this case is that we should not use as a reference either the fastest  $m + b$  or the slowest  $m + b$  clocks in the system. The other requirement, that  $\max_{i \in G1} f_{p_i}(N, m) - \min_{j \in G2} f_{p_j}(N, m) \geq m$  is not affected by benign failures (why is this the case?). Putting both together, we conclude that we must have  $N \geq 3m + 2b + 1$ .

(3) Since it takes  $5N$  time to run the algorithm and only 10% of the time is available to do so, we must have  $0.1R = 50N$ , i.e.,  $R = 50N = 50(3m + 1)$ . Over this time, clocks can diverge by at most  $2\rho R = 2 \times 10^{-6} \times 50(3m + 1) = (3m + 1) \times 10^{-4}$ .