

COSC-373: HOMEWORK 4

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Question 1. Each node v executes as follows.

Each round:

- (1) Pick a uniformly random color $c(v)$ from the range $1, 2, \dots, 2 \deg(v)$
- (2) Send message $c(v)$ to all neighbors
- (3) If $c(v) \neq c(u)$ for all neighbors u , output $c(v)$ and halt

(Correctness) At each round a node v picks a color $c(v)$ uniformly at random from the range $1, 2, \dots, 2 \deg(v)$. Then, node v sends its chosen color $c(v)$ to all its neighbors. Similarly, node v would also receive colors from its active neighbors. If one of v 's neighbors has already halted, v uses the last color it received from the neighbor. For each neighbor u of node v , if $c(v) \neq c(u)$, the condition that neighboring vertices are assigned different colors is satisfied, so node v outputs $c(v)$ and halts. Therefore, this protocol produces a proper 2Δ coloring of G .

(Congestion) Since the protocol only requires nodes to send colors from the range $1, 2, \dots, 2\Delta$ to neighboring nodes, only messages of size $O(1)$ bits are being sent. Thus, the protocol is in the CONGEST model.

(Runtime) To show that the protocol produces a proper 2Δ coloring of G in $O(\log n)$ rounds, first define the random variable X_v for whether a node v halts in a given round. Specifically, X_v is 1 if node v halts in the given round, and 0 otherwise. For a given round, since node v has $\deg(v)$ neighbors, its neighbors can choose at most $\deg(v)$ distinct colors from each other. We also know that node v chooses uniformly at random from $2 \deg(v)$ colors. As such, the probability that node v chooses the same color as one of its neighbors, is at most $\frac{\deg(v)}{2 \deg(v)} = \frac{1}{2}$. It follows that the probability $\mathbb{P}(X_v)$ that node v halts in a given round (i.e., choosing a different color from its neighbors) is

$$\begin{aligned} \mathbb{P}(X_v) &\geq 1 - \frac{1}{2} \\ &= \frac{1}{2}. \end{aligned}$$

Hence, the expected value $\mathbb{E}(X_v)$ of node v halting in a given round is

$$\begin{aligned} \mathbb{E}(X_v) &\geq 1 \cdot \frac{1}{2} + 0 \cdot \frac{1}{2} \\ &= \frac{1}{2}. \end{aligned}$$

Next, define the random variable X for the number of nodes that halt in a given round. Given the set of nodes V for graph G , we have that

$$X = \sum_{v \in V} X_v .$$

Taking the expected value on both sides, we get

$$\begin{aligned}
 \mathbb{E}(X) &= \mathbb{E}\left(\sum_{v \in V} X_v\right) \\
 &= \sum_{v \in V} \mathbb{E}(X_v) \\
 &\geq \sum_{v \in V} \frac{1}{2} \\
 &= \frac{1}{2}n
 \end{aligned}$$

Thus, in expectation, at least $\frac{1}{2}$ of all nodes halt in each round. If $n = n_0, n_1, \dots, n_k$ are the number of active nodes after rounds $0, 1, \dots, k$, we have that

$$\mathbb{E}(n_k) \leq \frac{1}{2^k} \cdot n.$$

Taking $k = 4 \log n$, we get

$$\begin{aligned}
 \mathbb{E}(n_k) &\leq \frac{1}{2^{4 \log n}} \cdot n \\
 &= \frac{1}{n^4} \cdot n \\
 &= \frac{1}{n^3}.
 \end{aligned}$$

By Markov's Inequality, it follows that $\mathbb{P}(n_k \geq 1) \leq \frac{1}{n^3}$. That is, after $4 \log n$ rounds, the probability that there are one or more active nodes is at most $\frac{1}{n^3}$. Therefore, the protocol produces a proper 2Δ coloring of G in $O(\log n)$ rounds with high probability.

Question 2. TODO

Question 3. TODO