Network Fairness Ambivalence: When Does Social Network Capital Mitigate or Amplify Unfairness?

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ABSTRACT

What are the necessary and sufficient conditions under which multi-hop dissemination strategies decrease rather than increase inequity within social networks? Our analysis of various strategies suggests that this largely depends on a limit related to the degree of homophily in the network.

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1 INTRODUCTION

Networks reflect real-life inequity present in how people connect and interact across gender, racial, and socioeconomic differences. In turn, this can directly impact how individuals bear access to opportunities that are often disseminated through the network itself. While networks are by nature used to expand the reach of information, they are increasingly scrutinized for the way their skewed dissemination contributes to or even reinforces unequal access to opportunities. Opportunities can be disseminated by people passing them on to their connections, which makes a node’s degree important in the graph as it affects the number of pathways between itself and nodes representing people who hold access to opportunities.

Assessing the impact of how network biases affect fairness in dissemination is a problem that has been well-studied through the lens of individuals passing information or opportunities through their 1-hop neighborhood. The results have often shown disparate treatment towards minority groups in the network, whose members typically find themselves in a disadvantaged position in the network compared to the majority [5]. However, what remains unclear is what occurs when one tries to bypass the lens of simply reaching out to the 1-hop neighborhood, by looking at further-hop neighborhoods, which represent connections of connections and beyond. Does this paradigm provide a sense of greater equity, or does it exacerbate the disparity between the two groups? Recent research has begun to explore fairness beyond immediate connections by focusing on specific nodes, like influencers [7], or through advanced recommendation algorithms that select specific connections [8]. In research that aligns closely with our own, Fabbi et al [4] have illustrated the critical influence of homophily and minority representation in determining the possibility of mitigating first-hop biases in broader network connections. However, their investigation stops short of providing a theoretical framework.

Our primary contribution is to address this question by establishing a sufficient and necessary theoretical condition and validating the phenomena using four real-world datasets. We start by utilizing a widely recognized network model that captures key elements of network bias; this bias arises from varying group sizes and individuals’ preference to connect with other similar individuals, often leaving minority group members with fewer direct connections.

Through empirical analysis of four real-world networks, we demonstrate that the perils and merits of dissemination are not only theoretical but align with our practical findings. We also present an example of a key application of our findings with a scenario of individuals who leverage their personal network to seek job referrals. Overall, our results suggest that online platforms designing algorithms to promote opportunities to multi-hop connections must carefully take into account network metrics measuring group size and homophily in order to avoid amplifying bias against marginalized groups on their platforms.

2 METRIC AND MODEL

Suppose we have an unweighted, undirected social network with nodes belonging to one of two groups, labeled red and blue, where the red group represents the minority and the blue group represents the majority. To perform rigorous analysis, we need to agree on a network-growth mode. Here, we adapt the widely-used Biased Preferential Attachment (BPA) Model [2], because this homophilic network model is known to reproduce network glass-ceiling effect – the difference in the access of opportunities that is more pronounced among people with the most social capital. This model reflects two well-observed network growth mechanisms: rich-get-richer [1][3] – existing members with higher degree are likely to attract new connections than the ones with lower degree, and homophily [6] – members tend to connect with members from the same group. Homophily along with minority ratio: the ratio of the minority group in the population are the two key parameters affecting network growth.

We define the $k$-hop neighbors of $u$ as the set of nodes whose shortest path to $u$ in $G$ is of length $k$, and the $k$-hop degree as the number of such nodes. Suppose there is a sequence of networks that grows by one node per time-step, infinitely. Our fairness metric
defines unfairness in $k$-hop dissemination against red nodes occurs if the average number of $k$-hop neighbors for a red node is lower than that of a blue node, as the graph size goes to infinity.

3 IMPACT OF MULTI-HOP DISSEMINATION

We took this network constructed under this BPA model, analyzing which in turn increases the chance of expanding their higher-hop with $k$, which we also prove is less than the minority to majority ratio, higher-hop will occur if and only if our condition is met. If the problem—the network effect—could be modeled and analyzed such as job referrals. We present how one particular factor of the

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Interestingly, this ratio for 2-hop is the same as for any $k$-hop with $k > 2$. The intuition is that asymptotically both red and blue nodes extend their $k$-hop neighbors mainly through their direct blue neighbors. Hence the ratio is essentially the ratio of the number of blue neighbors for red nodes over the one for blue nodes.

We observe that higher-hop alleviates the bias found in the 1-hop when the minority ratio is small, and the tendency to accept a connection from the other group (homophily) is large. The intuition behind this is that red nodes connect to their higher-hop neighbors through their 1-hop neighbors. Among their 1-hop neighbors, the blue neighbors have much higher degrees than the red neighbors. When there is a limited proportion of red nodes in the network and the tendency of red nodes to accept blue connections is large, the chance of a red node connecting to a red node becomes small, which in turn increases the chance of expanding their higher-hop neighbors though blue 1-hop neighbors and leverages the 1-hop bias in the second hop.

Additionally, when the homophily is pronounced, the 1-hop ratios and $k$-hop ratios have different limits; specifically, the 1-hop ratio goes to the minority population ratio as expected in [2], while the $k$-hop ratio goes to 0 for $k > 1$. The intuition for the higher-hop ratio is that red nodes connect to their higher-hop neighbors through their direct neighbors. Among the direct neighbors, the blue neighbors have much higher degrees that asymptotically dominate the count of higher-hop neighbors for red nodes. When homophily is pronounced, red nodes have limited blue friends, which restricts the red nodes from expanding higher-hop neighbors.

As our results show, the marginal benefit from going to the higher-hop will occur if and only if our condition is met. If the condition fails to be met, then the improvement from going to the 1-hop to the higher-hop strategy may be non-existent or even disadvantageous.

4 FAIRNESS IN JOB REFERRALS

One potential application of our findings we found abides in the realm of using professional networks for passing on opportunities such as job referrals. We present how one particular factor of the problem—the network effect—could be modeled and analyzed to understand how networks can affect inequality in seeking job referrals.

Job opportunity dissemination is the act of a job seeker asking another individual for assistance in acquiring a job referral under certain job-seeking strategies, in which the individual can either reject the request or accept the request. Accepting the request can be done by agreeing to provide a formal referral to the company they are employed at, agreeing to pass on their request to other people in their network, or performing actions such as writing a recommendation letter for the seeker or similar forms of help.

Here, we define unfairness as inequality in the total number of people willing to help the job seeker to get a referral. We assume that each user $u$ in the network has an attention parameter, the chance that $u$ will actually see and act on a request from an individual for help in their job referral search and forward it among people $u$ has access to.

We model first a linear strategy: a job seeker $u$ sends a job referral assistance request to potentially all neighbors. With a probability based on attention, a neighbor refuses to provide help, in which case the thread of referral request terminates; otherwise the neighbor agrees to help: in the case of $k = 1$, the process stops at hop 1; if $k > 1$, the neighbor passes the request to their own neighbors, and the referral assisting thread repeatedly moves to the next hop until it reaches $k$ hops or terminates due to rejection. Under this strategy, allowing higher-hop job referrals would benefit the minority if the condition in the previous section is satisfied.

We then model different strategies, assuming instead that seekers aim at a limited number of job referral requests within their $k$-hop neighborhood. We refer to those as an inquiry strategies. We found that when the number of referral requests is kept constant, the impact of multi-hop referral on fairness is determined by the inquiry strategies employed and does not vary with network conditions.

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