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Citation: Zhang, Yiguang, Han, Jessy Xinyi, Mahajan, Ilica, Bengani, Priyanjana and Chaintreau, Augustin. 2021. "Chasm in Hegemony: Explaining and Reproducing Disparities in Homophilous Networks."

As Published: https://doi.org/10.1145/3410220.3460109

Publisher: ACM|Abstract Proceedings of the 2021 ACM SIGMETRICS / International Conference on Measurement and Modeling of Computer Systems

Persistent URL: https://hdl.handle.net/1721.1/146025

Version: Final published version: final published article, as it appeared in a journal, conference proceedings, or other formally published context

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Chasm in Hegemony: Explaining and Reproducing Disparities in Homophilous Networks

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ABSTRACT

In networks with a minority and a majority community, it is well-studied that minorities are under-represented at the top of the social hierarchy. However, researchers are less clear about the representation of minorities from the lower levels of the hierarchy, where other disadvantages or vulnerabilities may exist. We offer a more complete picture of social disparities at each social level with empirical evidence that the minority representation exhibits two opposite phases: at the higher rungs of the social ladder, the representation of the minority community decreases; but, lower in the ladder, which is more populous, as you ascend, the representation of the minority community improves. We refer to this opposing phenomenon between the upper-level and lower-level as the *chasm effect*. Previous models of network growth with homophily fail to detect and explain the presence of this chasm effect. We analyze the interactions among a few well-observed network-growing mechanisms with a simple model to reveal the sufficient and necessary conditions for both phases in the chasm effect to occur. By generalizing the simple model naturally, we present a complete bi-affiliation bipartite network-growth model that could successfully capture disparities at all social levels and reproduce real social networks. Finally, we illustrate that addressing the chasm effect can create fairer systems with two applications in advertisement and fact-checks, thereby demonstrating the potential impact of the chasm effect on the future research of minority-majority disparities and fair algorithms.

CCS CONCEPTS

• **Theory of computation** → **Social networks**; • **Networks** → **Network simulations**; **Network performance analysis**; **Network dynamics**;

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SIGMETRICS '21 Abstracts, June 14–18, 2021, Virtual Event, China
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ACM ISBN 978-1-4503-8072-0/21/06.
https://doi.org/10.1145/3410220.3460109

KEYWORDS

structural bias in social networks; fairness of fake news detection.

ACM Reference Format:
Yiguang Zhang, Jessy Xinyi Han, Ilica Mahajan, Priyanjana Bengani, and Augustin Chaintreau. 2021. Chasm in Hegemony: Explaining and Reproducing Disparities in Homophilous Networks. In *Abstract Proceedings of the 2021 ACM SIGMETRICS / International Conference on Measurement and Modeling of Computer Systems (SIGMETRICS '21 Abstracts), June 14–18, 2021, Virtual Event, China.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3410220.3460109

1 INTRODUCTION

The "glass-ceiling" effect has multiple real-world applications; it is invoked when describing the invisible barrier that women — or any minority group — hit in their career as they approach the upper echelons of management [2][3]. The top of the hierarchy has been well studied, whereas research on minority representation in the rest of the social hierarchy has received less attention. Having a complete characterization of social disparities at all levels of the hierarchy helps tackle questions including at what point a minority group starts experiencing a systemic disadvantage, and at what rung of the ladder – if any – are minorities fairly represented.

We tackle these questions leveraging real-world datasets (QQ, WhatsApp, and Instagram) in an attempt to understand the distribution of minority representation across the entire hierarchy. In order to talk about the advantage or disadvantage of the minorities, we have to agree on a measure of success in a social network. Following the conventional approach that sees network edges as the network's "social capital.", we define successful members in a friendship (unipartite) network to be people with a large number of friends, and define successful groups in a group-member (bipartite) network to be groups with many members.

Our main finding is the surprising but repeated evidence that the ratio of people belonging to a minority group initially increases as one moves up in the lower layers of the hierarchy, before it reaches a plateau and drops, as shown in Figure 1. We refer to this effect as a "chasm" because people who observe the lower or upper layer of a hierarchy might agree that a systemic bias is present but would hastily claim it is in opposite directions. This is in striking contrast to the monotonic behavior one would expect in all previous systemic models of hegemonic biases. As we prove that

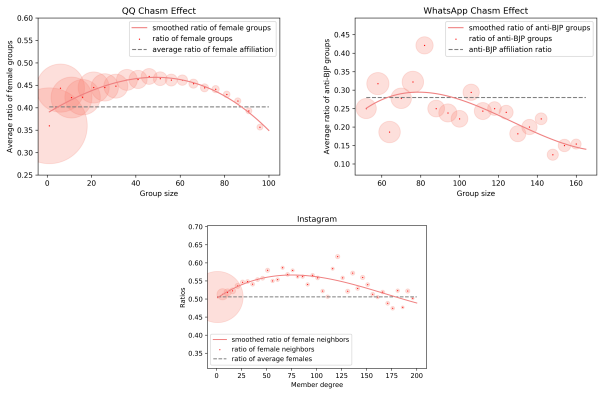

Figure 1: We observe that in both the QQ dataset (bipartite network) and the WhatsApp dataset (bipartite network), the ratio of minority groups (vs majority groups) is not monotone. As expected from the glass-ceiling effect, the ratio decreases for large group sizes; however, it increases for small groups, which constitutes a larger parts of all groups. A similar trend is observed in the Instagram network (unipartite network) as well: the ratio of female connections a member has first increase, then decreases. The radii of light-red circles in the bipartite plots are proportional to groups counts, and the radii of light-red circles in the bipartite plots are proportional to member counts.

previous models cannot explain our observation, we also provide the first generative model that offers a simple explanation and is general enough to apply broadly.

The question we ask in this paper addresses the causes of this chasm effect. What are the mechanisms that interact with each other to create both the glass-ceiling effect and the chasm effect, and in particular, how do social networks play a role in creating these two effects?

Previous studies on the glass-ceiling effect have provided mechanisms that capture the glass-ceiling effect [1]. However, the same mechanisms do not capture the chasm effect we have observed. In this paper, we primarily focus on bi-affiliated bipartite networks, where the network is partitioned into groups and members, and each member and each group has an independent or collective (respectively) viewpoint that favors the minority or majority. We are interested in these bipartite networks for two reasons: (1) the nature of bipartite networks is less understood but more intriguing due to their complexity; (2) many social platforms, such as WhatsApp, are now group-based where members find communities of their interests within the larger network. We analyze the interactions among a few well-observed network-growing mechanisms with a simple model to reveal the sufficient and necessary conditions for both the glass-ceiling effect and the chasm effect to both be present. We further generalize the simple model naturally and present a complete bi-affiliation bipartite network-growth model. We demonstrate our proposed model's effectiveness through both mathematical proofs and data synthesis. Our generative model is the first to capture the chasm effect in social disparities.

This study has important practical applications, especially as it puts a spotlight on structural biases in bipartite networks and hints at ways to address them. More specifically, the new idea of a chasm effect we put forward provides a foundation for allocating resources differently in diverse settings to minimize bias among those people who constitute a large portion of the population that are more disadvantaged and vulnerable. We present two examples taken from different contexts: (1) (gender fairness) we aim to provide recruiters with a better job placement strategy if they want to diversify their pool of candidates; (2) (political fairness) in politics-related group chats where conversations are not accessible outside the immediate community, we aim to show how fake-news can have more of an adverse impact on the minority population in a constrained environment.

As a summary, our main contributions are:

- We prove the existence of the chasm effect with empirical evidence from real-world datasets, and characterize the phenomenon in-depth to provide a more complete picture of social parities. That is, we show that the ratio of the minority community does not decrease monotonically as we move up the hierarchy.
- We analyze the interactions among network-growth mechanisms and derive the necessary mechanisms for both the chasm effect and the glass-ceiling effect to be present in bipartite networks.
- We propose a complete bipartite bi-affiliation network-growth model that generalizes the necessary mechanisms discussed in Section 4. The generalized model is capable of reproducing real-world social networks. Under the generalized model, we provide proofs to show that both types of entities in the generated networks have power-law degree distributions, and specify the sufficient and necessary conditions mathematically for both the glass-ceiling effect and the chasm effect to present.
- Finally, we provide two real-world applications of our findings, job advertisement and fact-checking, where the chasm effect could impact the direction of bias, thereby motivating the importance of considering the chasm effect.

Those results together suggest that the chasm effect can be observed, at least frequently in online networks which may exhibit simple selective homophily dynamics, and has consequences. We urge some caution as our results do not, however, prove that the chasm is unavoidable: Some social networks (and, under some conditions, our general model) can exhibit a systemic monotonic bias against minority groups at *all* level of the hierarchy.

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