Granovetter's Weak-Tie Paradox in Scientific Collaboration Networks: Resolution and Implications for Scientific Success

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The relationship between tie strength and network structure is a cornerstone of social network theory, most notably captured by Granovetter's weak tie hypothesis. In its quantitative form, the theory predicts a monotonically increasing relationship between tie strength and neighborhood overlap, reflecting the idea that strong ties are embedded within cohesive communities, while weak ties act as bridges between them. This prediction has been empirically confirmed — at least to varying degrees — in several real-world systems, including large-scale mobile communication networks.

However, notable counterexamples have been reported. One of the most prominent is the scientific collaboration network, where empirical studies have suggested an apparent violation of Granovetter's theory: for the majority of edges, neighborhood overlap decreases with increasing edge weight, seemingly contradicting the expected monotonic relationship. This discrepancy has raised important questions about the universality of the weak tie hypothesis and its applicability to knowledge-driven systems such as science.

We revisit this problem using large-scale bibliometric data derived from the DBLP database. We demonstrate that the apparent disagreement with Granovetter's theory is not intrinsic to the scientific collaboration network itself, but rather arises from improper definitions of tie strength (edge weight) and neighborhood overlap. In particular, commonly used symmetric and aggregate measures fail to capture the inherently heterogeneous and asymmetric nature of scientific collaborations, where interactions between individuals often differ significantly in intensity and contribution.

To resolve this issue, we introduce an asymmetric definition of tie strength, based on the relative contribution of shared publications, and redefine neighborhood overlap in a way that is consistent with this asymmetry. Within this refined framework, we recover the expected structural pattern: a clear monotonic increase of neighborhood overlap with tie strength, thereby restoring full agreement with Granovetter's theory.

Beyond resolving this fundamental inconsistency, our results also shed light on the role of weak ties in scientific success. Importantly, this constitutes the first large-scale empirical verification of the second part of Granovetter's hypothesis in the literature, concerning the functional role of weak ties as bridges facilitating access to novel, non-redundant information. We show that weak ties — understood as links connecting otherwise distant regions of the collaboration network — are strongly associated with higher scientific impact. Scientists embedded in networks with weaker ties tend to achieve higher citation counts and h-indices, even when controlling for productivity. Similarly, research teams connected via weaker ties produce more highly cited work, supporting the idea that access to diverse, non-redundant information fosters innovation.