Link communities reveal multiscale complexity in networks

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Abstract

Networks have become a key approach to understanding systems of interacting objects, unifying the study of diverse phenomena including biological organisms and human society[1, 2, 3]. One crucial step when studying the structure and dynamics of networks is to identify communities[4, 5]: groups of related nodes that correspond to functional subunits such as protein complexes[6, 7] or social spheres[8, 9, 10]. Communities in networks often overlap[9, 10] such that nodes simultaneously belong to several groups. Meanwhile, many networks are known to possess hierarchical organization, where communities are recursively grouped into a hierarchical structure[11, 12, 13]. However, the fact that many real networks have communities with pervasive overlap, where each and every node belongs to more than one group, has the consequence that a global hierarchy of nodes cannot capture the relationships between overlapping groups. Here we reinvent communities as groups of links rather than nodes and show that this unorthodox approach successfully reconciles the antagonistic organizing principles of overlapping communities and hierarchy. In contrast to the existing literature, which has entirely focused on grouping nodes, link communities naturally incorporate overlap while revealing hierarchical organization. We find relevant link communities in many networks, including major biological networks such as protein–protein interaction[6, 7, 14] and metabolic networks[11, 15, 16], and show that a large social network[10, 17, 18] contains hierarchically organized community structures spanning inner-city to regional scales while maintaining pervasive overlap. Our results imply that link communities are fundamental building blocks that reveal overlap and hierarchical organization in networks to be two aspects of the same phenomenon.

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