Social Networks xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Social Networks

journal homepage: www.elsevier.com/locate/socnet

The contagion effects of repeated activation in social networks

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ARTICLE INFO

Article history:
Available online xxx

Keywords:
Interdependence
Temporal dynamics
Coordination
Thresholds
Critical mass
Diffusion
Collective action
Agent-based simulation

ABSTRACT

Demonstrations, protests, riots, and shifts in public opinion respond to the coordinating potential of communication networks. Digital technologies have turned interpersonal networks into massive, pervasive structures that constantly pulsate with information. Here, we propose a model that aims to analyze the contagion dynamics that emerge in networks when repeated activation is allowed, that is, when actors can engage recurrently in a collective effort. We analyze how the structure of communication networks impacts on the ability to coordinate actors, and we identify the conditions under which large-scale coordination is more likely to emerge.

1. Introduction

Recent years have seen the emergence of massive events coordinated through large, decentralized networks. These include political protests and mobilizations like the Occupy movement of 2011 (Conover et al., 2013; González-Bailón and Wang, 2016), the Gezi Park demonstrations of 2013 (Barberá et al., 2015), or the growth of the #BlackLivesMatter campaign during the 2014 protests in Ferguson (Freelon et al., 2016). These collective events offer examples of the coordinating potential of communication networks – which, increasingly, emerge through the use of online technologies. This paper pays attention to the coordination dynamics that allow a small movement, a new campaign, or an unknown hashtag to rise to prominence. We present a formal model that allows us to answer the following question: How do coordination dynamics unfold to make individual actions (e.g. using an emerging hashtag, endorsing a mobilization) converge over time? Our model aims to disentangle the mechanisms that drive the emergence of decentralized, large-scale coordination. The goal is to identify the conditions under which coordination is more likely to arise from networks that are constantly pulsating with information.

Threshold models have become the standard for how we think about interdependence and the collective effects of social influence (Granovetter, 1978; Granovetter and Soong, 1983; Schelling, 1978). As originally formulated, the activation of individual thresholds responds to global information: the group of reference is assumed to be the same for all actors. In later developments of the basic model, networks were introduced to add local variance to social influence: the group of reference was now determined by connectivity in the network, which changed from actor to actor (Valente, 1996; Watts, 2002). These different variations of the threshold model share two important elements: first, activation is modelled as a step function that goes from 0 to 1 when thresholds are reached; and second, thresholds can only be reached once, that is, activation is assumed to be a one-off event. Our model aims to relax these assumptions and allow actors to repeatedly activate as a function of the dynamics unfolding in the rest of the network. We argue that this modification aligns our model of contagion more closely with what is observed in many empirical networks – in particular, with the communication dynamics observed in online networks and the temporal autocorrelation that results from those dynamics.

Online campaigns are an important manifestation of this type of repeated activation, and they offer a good example of what we

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https://doi.org/10.1016/j.socnet.2017.11.001

mean by "coordination": a form of organizational effort to attract public attention or direct mobilization logistics on the ground. The Black Lives Matter movement, for instance, gained traction when the hashtag was first adopted in social media in 2013, which fueled what has been labeled as "an Internet-driven civil rights movement" (Eligon, 2015, see also Day, 2015). There is agreement that the movement consolidated with its first peaceful demonstrations in Ferguson in 2014 (Bosman and Fitzsimmons, 2014); but this move "from hashtag to the streets" stands as a new model for how "liberations groups in the twenty-first century can organize an effective freedom rights campaign" (Ruffin, 2015). Online networks were central to the coordination efforts of this campaign; here, we aim to illuminate the mechanisms that explain why.

In the context of empirical examples like the Black Lives Matter movement, activation involves repeatedly using a specific hashtag to build momentum up to the point when large-scale coordination is achieved – i.e., the hashtag starts receiving global recognition, which can then be used to shape the public agenda or to help organize further mobilization efforts. The goal of our model is to abstract this element of repeated activation and build an analytical framework around it to answer three interrelated questions: How does the structure of interdependence, the variance in individual propensities to activate, and the strength of social influence affect contagion and the emergence of large-scale coordination? As with many analytical models, ours is a simplification of what is essentially a very complex reality. But it offers, we think, important insights into the counter-intuitive effects of networks in allowing coordination to emerge.

The rest of the paper proceeds as follows. First, we consider prior work analyzing coordination in networks, and the analytical choices made when modelling social influence. We introduce our model as a continuation of threshold models, well suited to analyze dynamics of adoption (e.g. joining a political movement) but not well equipped to analyze the dynamics of coordination that emerge amongst actors that are already part of a movement. We then describe our model in detail, highlighting the main differences compared to previous approaches and unpacking our assumed mechanisms. In sections five and six we present our findings, which we organize around two main questions: How do changes in network topology affect the emergence of coordination under different assumptions of social influence? And how does individual heterogeneity impact coordination dynamics? We close the paper with a discussion of our findings, especially as they relate to previous research on contagion in networks.

2. Coordination as a two-step selection process

We can think of coordination dynamics as a two-step selection process: in the first stage, actors decide if they want to join a movement; in the second stage, they coordinate their actions with those who also opted in. Most threshold models refer to the first stage, and they focus on the cascading effects of one-off activations – the decision, that is, to join a collective effort. These models belong to the more general theoretical tradition of diffusion research, which looks at how ideas or behavior spread in social systems (Rogers, 2003; Valente, 1995). Diversity in the motivation to adopt a behavior is modelled as a distribution of thresholds; what prior research shows is that the shape of this distribution is one of the key elements explaining the cascading effects of individual activations (Watts and Dodds, 2010). Contagion dynamics, however, also depend on the structure of ties and how that structure encourages or hinders spreading dynamics. Networks shape coordination dynamics by creating different centrality distributions, which allow specific individuals to be more or less influential (Freeman, 1979); and by opening more or less structural holes (Burt, 1992; also Girvan and Newman, 2002), which constrain opportunities for chain reactions to the extent that they delimit the routes that cascades can follow (Watts, 2002). Networks also delimit the size and the composition of the groups of reference surrounding a given actor and, therefore, the number of social signals each actor receives (Centola and Macy, 2007; Valente, 1996).

Most threshold models assume that activation happens only once and that, once activated, the change of state (from inactive to active) is permanent. This is the reason why threshold models are appropriate to capture the first stage of coordination dynamics – for instance, the decision to join a movement or start using a particular hashtag. The model we propose here, on the other hand, aims to capture dynamics of activation within adoption, that is, coordination amongst actors who already opted in and therefore have an interest in facilitating organizational efforts.

We have theoretical and empirical reasons to allow repeated activation to be the driving force of contagion dynamics. The empirical reason is that most instances of diffusion do not involve a single activation but many activations building up momentum in time. Before a hashtag becomes a trending topic, a period of buzz is first required; prior to a protest day, calls announcing the mobilization are distributed in waves. Actors decide whether they want to engage in an online conversation or take part in a protest. This is what threshold models can capture. What threshold models are not devised to capture is the period of information exchange that follows the act of joining a collective effort. During this period, social influence trickles intermittently as a function of the context that actors inhabit – that is, as a function of activity in the local networks to which they are exposed; and this context is not stationary: it changes, sometimes drastically, over time. Our model aims to capture this temporal dimension.

We also have a theoretical reason to relax the assumption of single activation. The intermittent dripping of information that social networks facilitate often leads to bursts of activity (Vazquez et al., 2006), as when news suddenly become trending topics (Lehmann et al., 2012; Wu and Huberman, 2007). Coordination dynamics underlie these bursts of activity: sudden peaks in communication require the adjustment of individual actions, that is, the alignment of many individual decisions so that everybody uses the same trending hashtag or talks about the same news at the same time.

These dynamics of coordination, and how they lead to collective outcomes like swift information cascades, trending topics, or viral hashtags, are overseen if activation is modelled as a permanent change of state – that is, if we only focus on the first stage of what is, in fact, a two-step process. Our model presumes that, once in the second stage, individual propensities to activate will be influenced by the network and the signals it transmits, which in turn results from how other actors are influenced and react to that influence over time. These dynamics aim to resemble more closely the dynamics observed in the context of large-scale mobilizations, where actors repeatedly engage in activities like spreading calls for action or increasing the salience of political hashtags (Barberá et al., 2015; Borge-Holthoefer et al., 2011; Budak and Watts, 2015; Conover et al., 2013; Jackson and Foucault Welles, 2015). Individual decisions to contribute to the flow of information, and the decisions of those connected to a focal actor, co-evolve over time; our analytical approach models that co-evolution explicitly.

As previous models, our model assumes that exposure to information is the driving force underlying contagion. What makes our model different from previous models is that failure to trigger a chain reaction depends not only on the distribution of thresholds or the impact of network structure on activation dynamics; it also depends on whether the network facilitates coordination, that is, an alignment of actions in time – which is an important organizational goal for social movements that want to gain public visibility in social media or use online networks to manage mobilization