KAIST Computer Science AALAB

When Does the Tipping Point Occur? : Analysis of Information Cascade in Social Networks

Seulki Lee (KAIST)
Kyomin Jung (KAIST)
Meeyoung Cha (KAIST)

Abstract

The tipping point—the moment beyond which a small-scale cascade process proceeds rapidly to become a global-scale cascade—has received great attention in academia and industry. However, little has been known on the exact conditions for when such tipping point happens in real networks. In this paper, we conduct numerical analysis of a popular cascade model, the linear threshold model, to understand the impact of network structures and user susceptibility, on tipping point. We make two interesting observations: (i) the occurrence of global cascade depends critically on the susceptibility of users, and (ii) when the conditions are met, a tipping point almost always exists regardless of the size and structure of the network.

Methodology

$s_v(t)$: State vector of each node
$y(t)$: Number of nodes having state 1
$A(t)$: A set of early adopter at time t

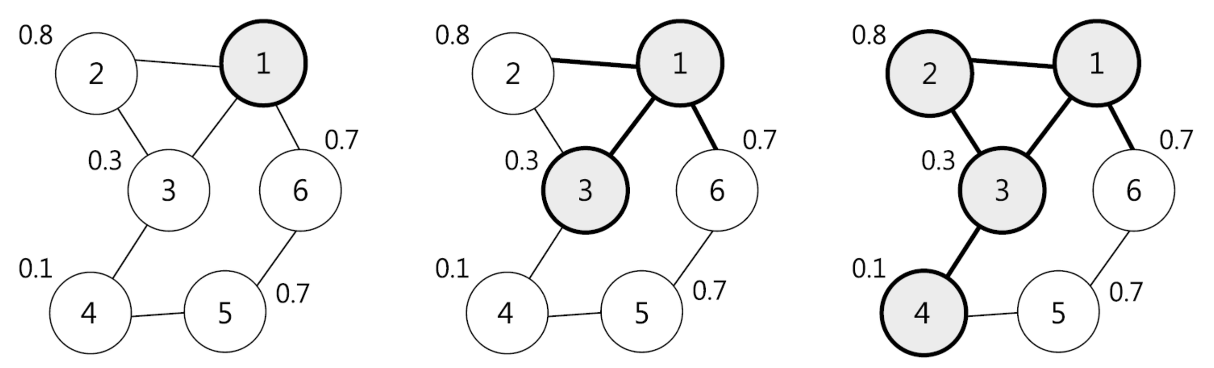
$$s_v = \begin{cases} 1 & \text{if } \phi_v \le \frac{x_v}{k_v}, \text{ where } x_v = \sum_{\{u,v\}\in E} s_u. \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Linear Threshold Process(A)

1. Given a set A of early adopters, set for $s_v = 1$, and for $v \in A$, and $s_v = 0$ for $v \notin A$.
2. Update the states of every node by equation (1).
3. Repeat step 2 until there is no state change of nodes.

Global cascade at tipping point

$$y(t^* + 1) = y(t^*) + \theta(|V|)$$



Step 1 Step 2 Step3

By increasing the size of $A(t)$ at each time step, we observed the occurrence of a tipping point

By the theorem below, we computed the existence and the value of the tipping point t^*, by binary search on t.

Theorem Let $G = (V, E)$ be a graph, and ϕ be a susceptibility vector on G. Let $A_1 \subset A_2 \subset V$ be any vertex subset, and let $A_3 = A_2 - A_1$. For $i = 1,2$, let $S_i(G, \phi)$ be the set of nodes having state 1 when the Linear Threshold Process(A_i) with G and ϕ finishes. Let $S_3(G, \phi)$ be the set of nodes having state 1 when the Linear Threshold Process($S_1(G, \phi) \cup A_3$) with G and ϕ finishes. Then, $S_2(G, \phi) = S_3(G, \phi)$.

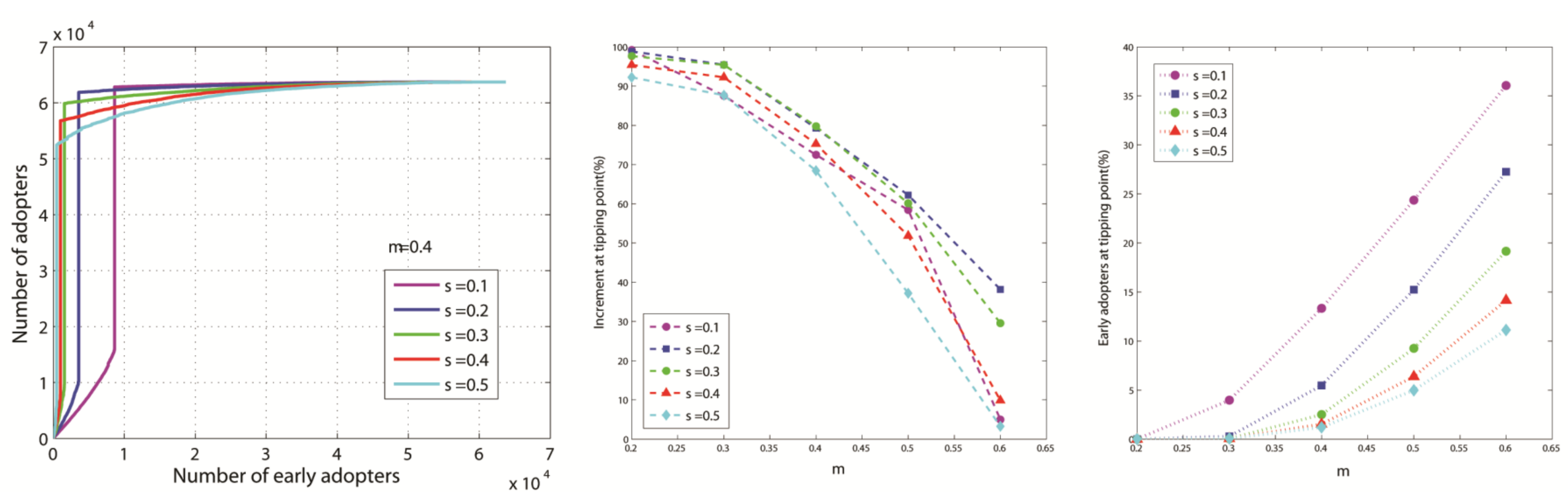
Simulations on OSNs

σ	Facebook					MySpace				
μ	0.1	0.2	0.3	0.4	0.5	0.1	0.2	0.3	0.4	0.5
0.1	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100
0.4	100	100	100	100	100	100	100	100	100	100
0.5	100	100	100	70.5	0.5	99	100	100	100	100
0.6	0	0	0	0	0	5.5	55	69.5	60	56.5

Table 1: The occurrence probability (%) of a tipping point for $\phi = N(\mu, \sigma)$.

Based on 200 simulations, Tipping point almost always occurred when the setting for susceptibility ϕ was right

Facebook (n=63,731, z=25.6)



Very similar results were obtained for both Facebook and MySpace, indicating that the conditions for tipping point have a week correlation with the network structure.

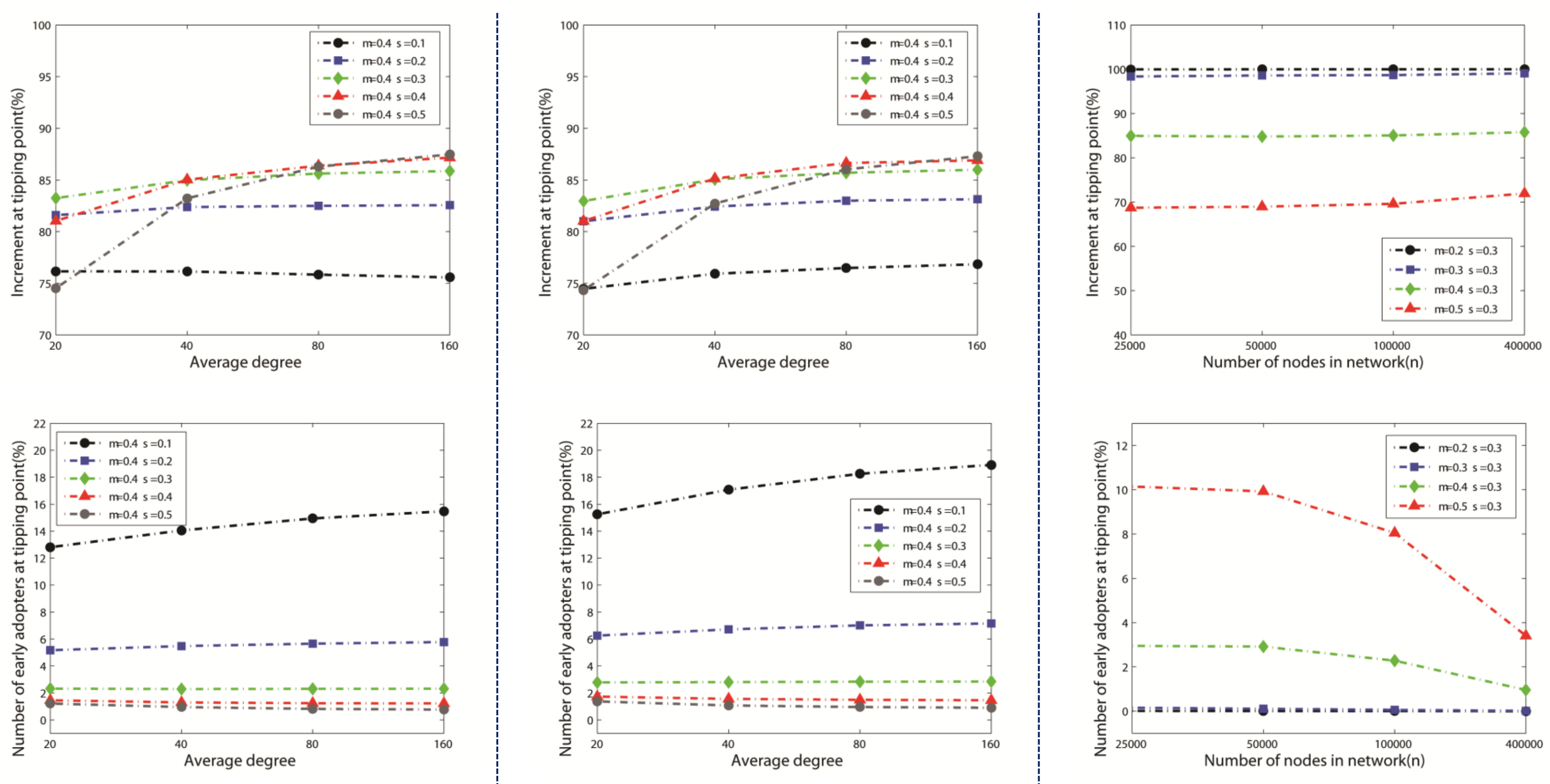
Simulations on Random Networks

σ	Barabási-Albert					Erdős-Rényi				
μ	0.1	0.2	0.3	0.4	0.5	0.1	0.2	0.3	0.4	0.5
0.1	100	100	100	100	100	100	100	100	100	100
0.2	100	100	100	100	100	100	100	100	100	100
0.3	100	100	100	100	100	100	100	100	100	100
0.4	100	100	100	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100	100	100	100
0.6	95.5	100	79	13	0	100	100	86	2.5	0

Table 2: The occurrence probability (%) of a tipping point for $\phi = N(\mu, \sigma)$.

Based on 200 simulations, Tipping point almost always occurred when the setting for susceptibility ϕ was right

ER graph (n=100,000) **BA graph (n=100,000)** **BA graph**



Strikingly similar results obtained for two independent random graphs.