Information Diffusion at Twitter

Stanislav Nikolov

OVERVIEW

- Theory:
  - simple model of information diffusion
- Experiment:
  - diffusion of a topic on Twitter.

MOTIVATION

- How do things spread in a network?
  - Cascading failure (finance, power grids, etc.)
  - Opinion
  - Behavior
  - Innovations
  - Rumors
- Why do some things spread and others don't?
- Can we detect (early) when something will spread?

OVERVIEW

- Theory:
  - simple model of information diffusion
- Experiment:
  - diffusion of a topic on Twitter.

TYPES OF DIFFUSION

- "Simple" vs. "complex"
- Simple – needs only one person
  - can happen **randomly** (e.g. disease)
- Complex – needs several people
  - **Awareness** (e.g. joke, event)
  - **Credibility** (e.g. rumor)
  - **Legitimacy** (e.g. occupy wall street)
  - **Persuasiveness** (e.g. "please RT")

DIFFUSION AS DECISION-MAKING

- What's a good decision rule?

DIFFUSION AS DECISION-MAKING

- What's a good decision rule?
- **Local** information + **threshold**:

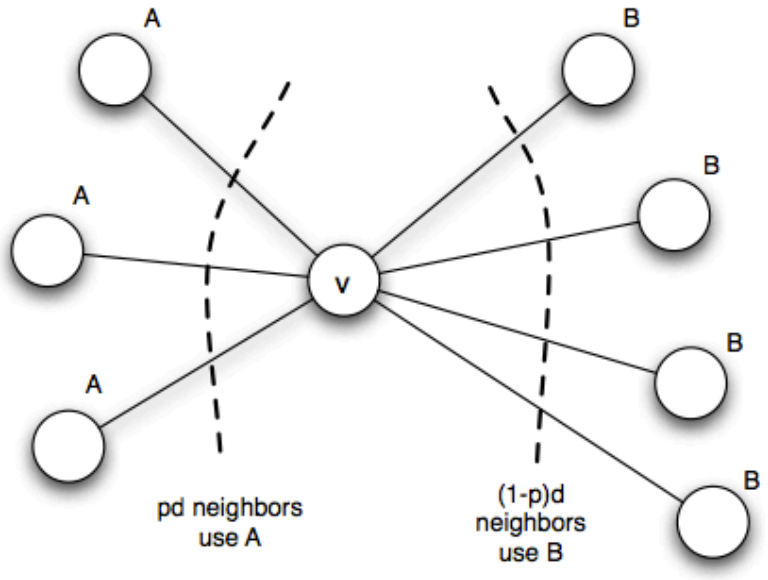

Figure 19.2: v must choose between behavior A and behavior B, based on what its neighbors are doing.

D. Easley, J. Kleinberg. Networks, Crowds, and Markets: Reasoning About a Highly Connected World. Cambridge University Press, 2010.

DIFFUSION AS DECISION-MAKING

- Game theoretic perspective – a **networked coordination game**

		w: A	w: B
v	A	a, a	$0, 0$
	B	$0, 0$	b, b

Figure 19.1: A-B Coordination Game

- if v and w both adopt behavior A, they each get a payoff of $a > 0$;
- if they both adopt B, they each get a payoff of $b > 0$; and
- if they adopt opposite behaviors, they each get a payoff of 0.

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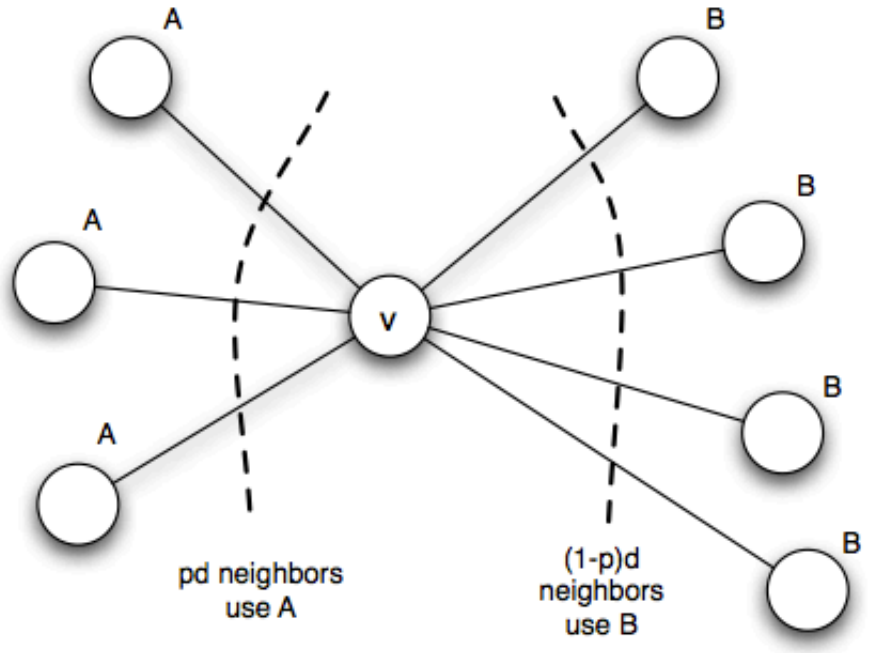
DIFFUSION AS DECISION-MAKING



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DIFFUSION AS DECISION-MAKING

A is the better choice if

$$pda \geq (1-p)db,$$

$$p \geq \frac{b}{a+b}.$$

$$q = b/(a+b)$$

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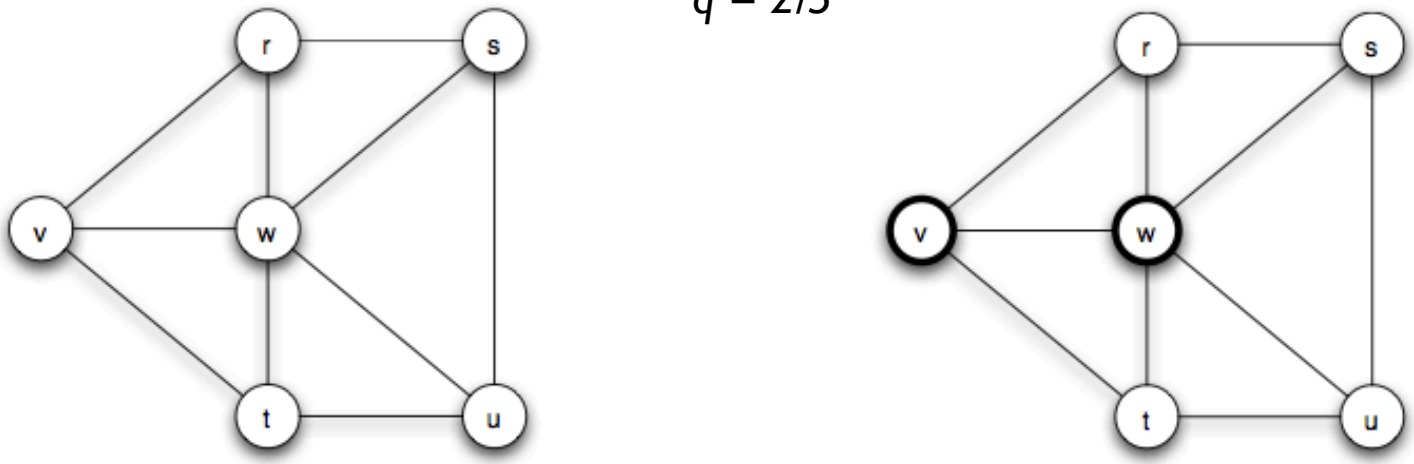
EXAMPLES

$q = 2/5$



(a) *The underlying network* (b) *Two nodes are the initial adopters*

Figure 19.3: Starting with v and w as the initial adopters, and payoffs $a = 3$ and $b = 2$, the new behavior A spreads to all nodes in two steps. Nodes adopting A in a given step are drawn with dark borders; nodes adopting B are drawn with light borders.

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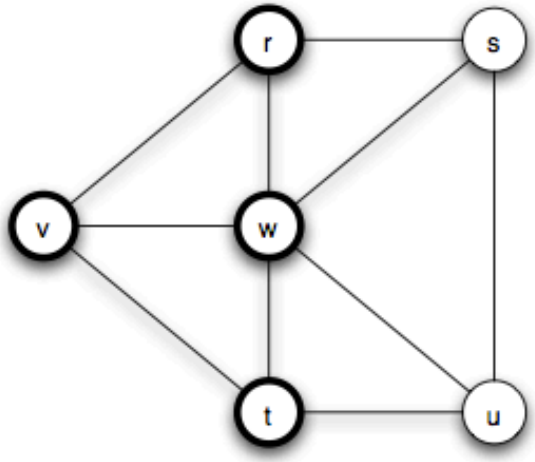
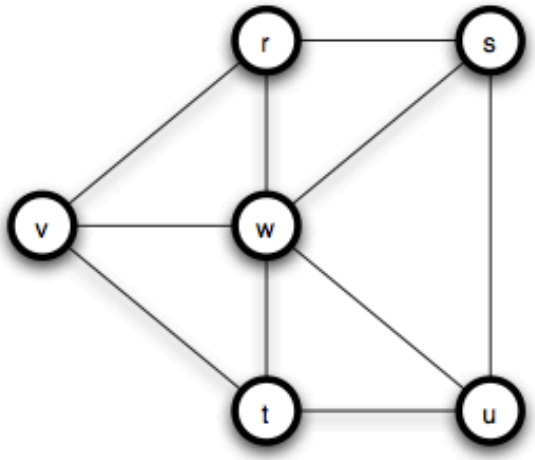
EXAMPLES



(c) *After one step, two more nodes have adopted*

q = 2/5



(d) *After a second step, everyone has adopted*

Figure 19.3: Starting with v and w as the initial adopters, and payoffs $a = 3$ and $b = 2$, the new behavior A spreads to all nodes in two steps. Nodes adopting A in a given step are drawn with dark borders; nodes adopting B are drawn with light borders.

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EXAMPLES

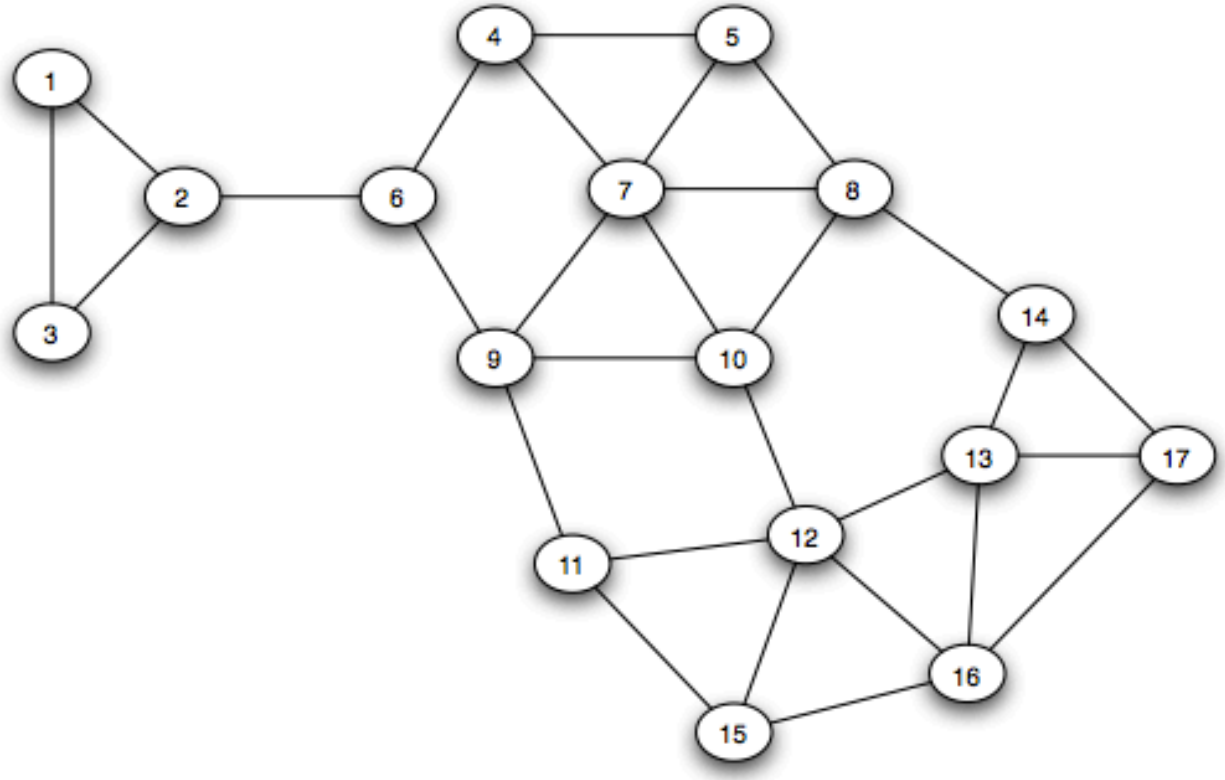

Figure 19.4: A larger example.

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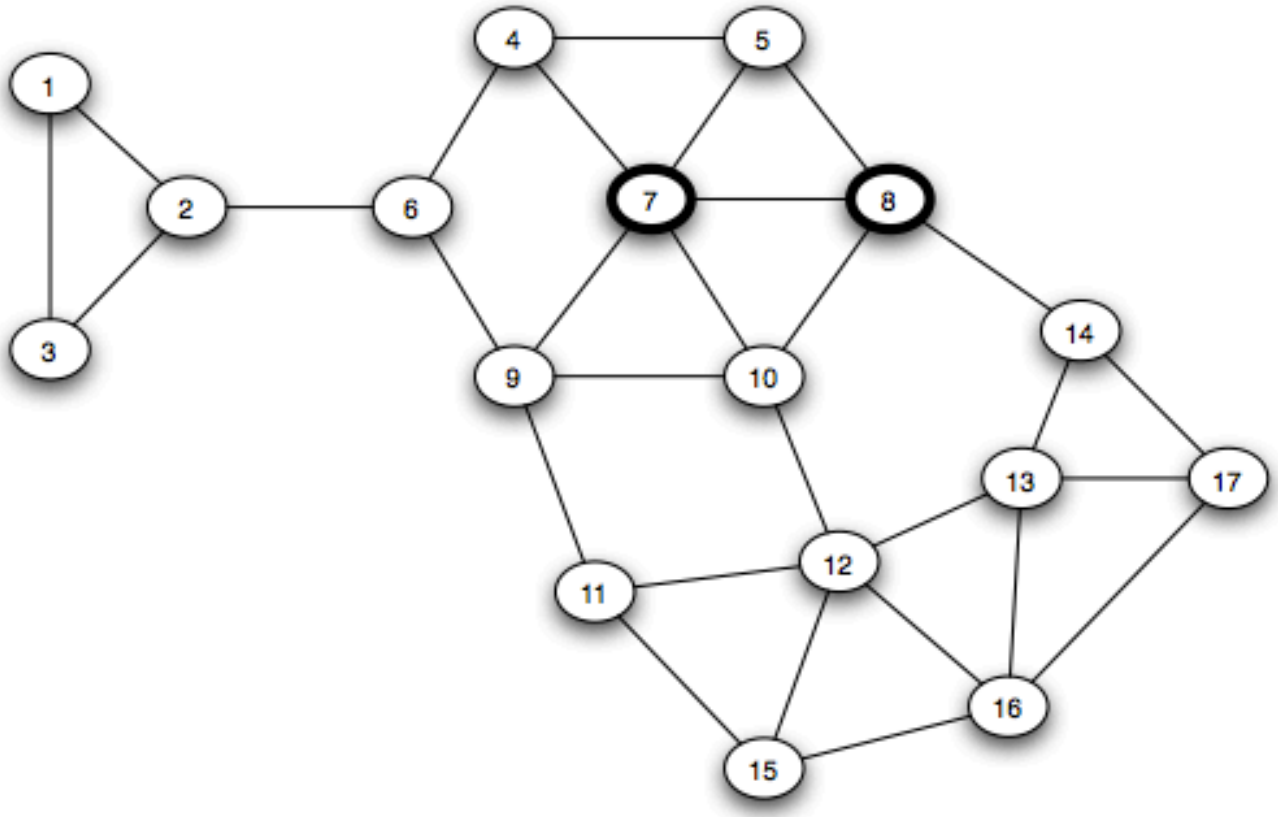
EXAMPLES



(a) *Two nodes are the initial adopters*

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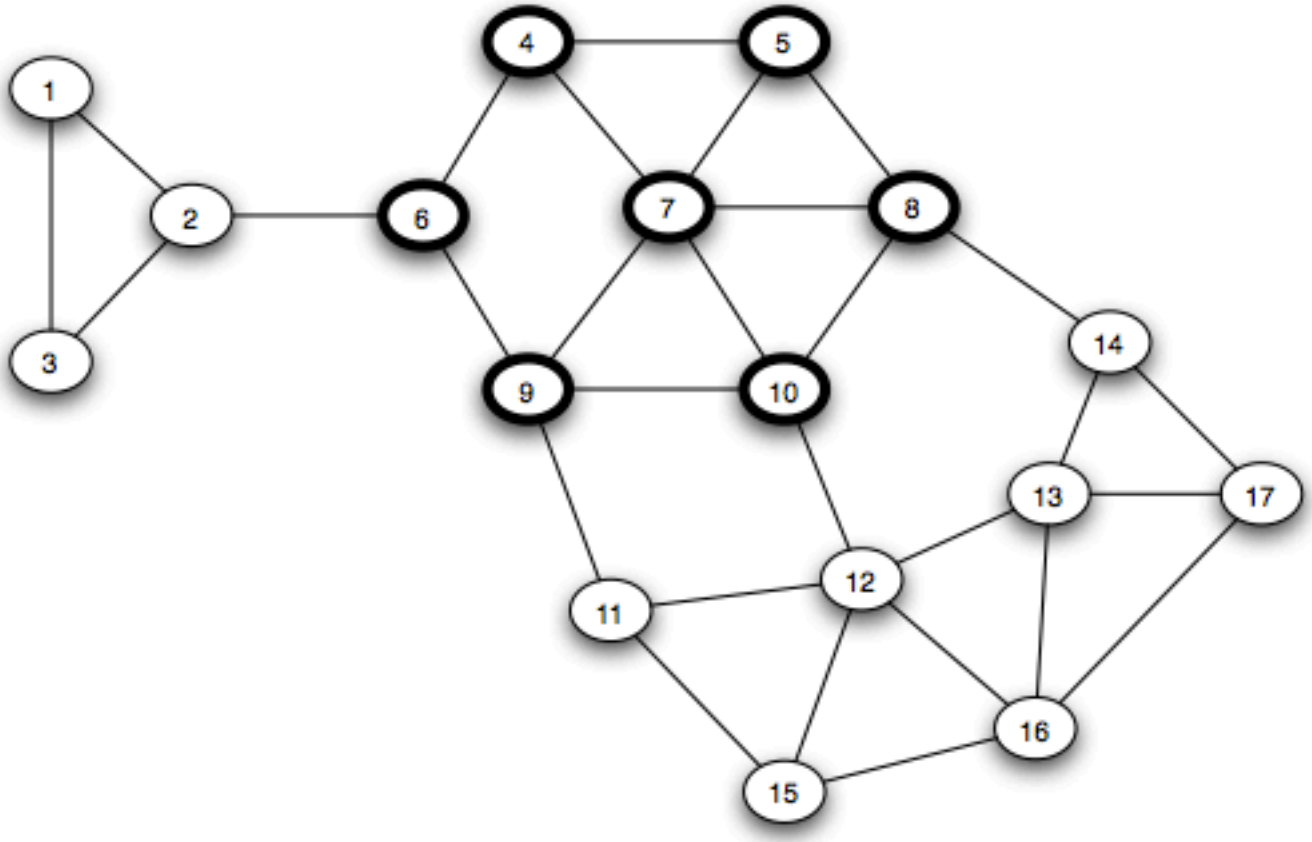
EXAMPLES



(b) *The process ends after three steps*

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THE ROLE OF CLUSTERS

- Clusters are obstacles to diffusion
- **Cluster of density p:** set of nodes such that each node in the set has p or greater fraction of its neighbors in the set.

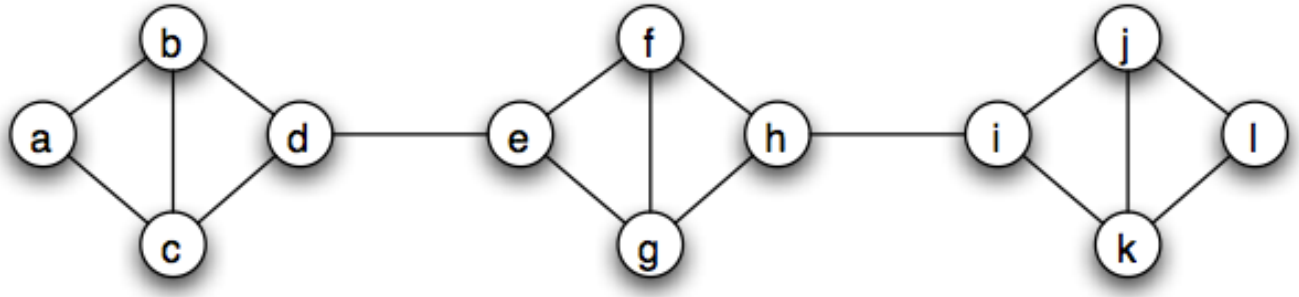

Figure 19.6: A collection of four-node clusters, each of density 2/3.

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THE ROLE OF CLUSTERS

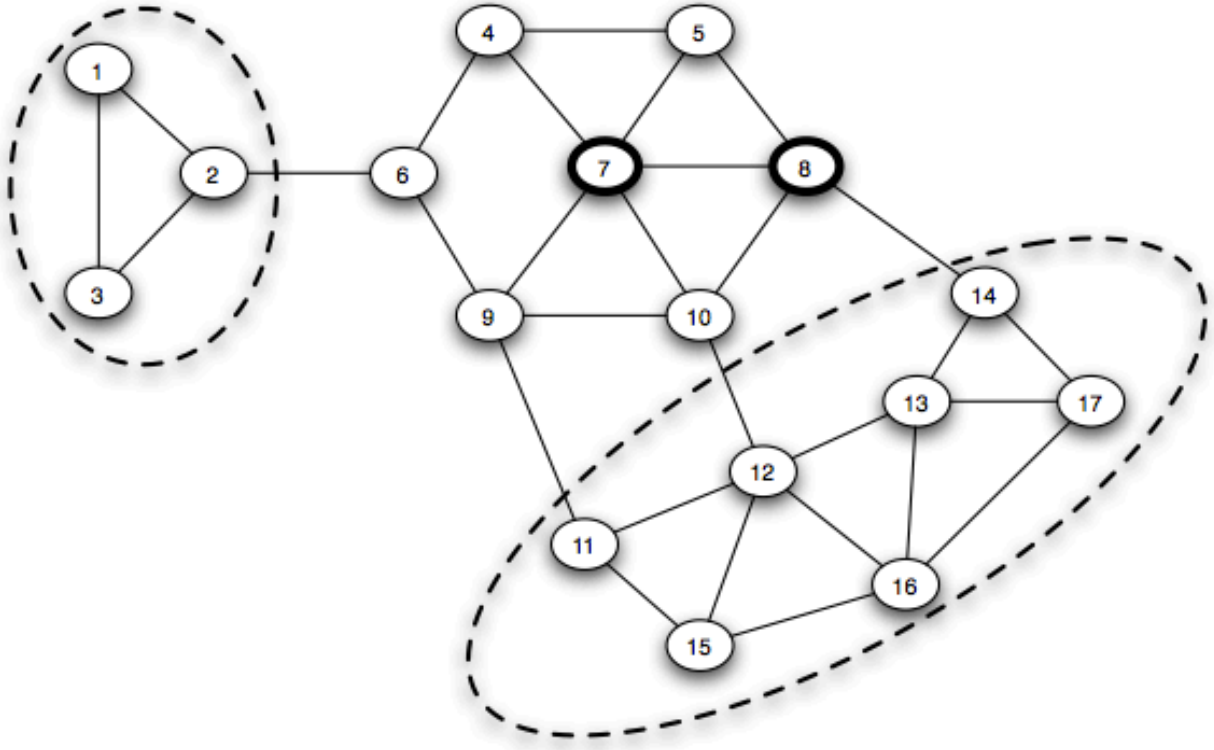

Figure 19.7: Two clusters of density 2/3 in the network from Figure 19.4.

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THE ROLE OF CLUSTERS

- Consider threshold *q*, and some initial participants.
- Claim:
  - diffusion will stop ⇐⇒ remaining network has a cluster of density greater than *1-q*

THE ROLE OF CLUSTERS

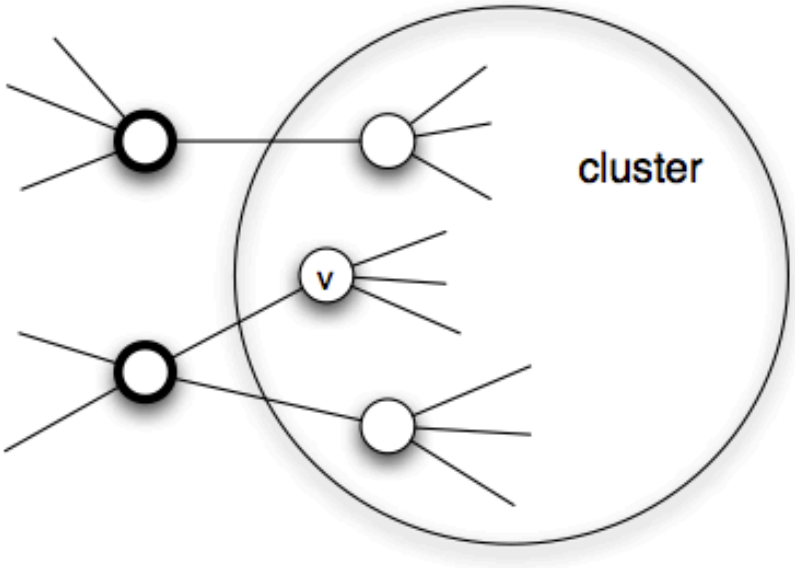

Figure 19.8: The spread of a new behavior, when nodes have threshold q, stops when it reaches a cluster of density greater than $(1 - q)$.

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OVERVIEW

- Theory:
  - simple model of information diffusion
- Experiment:
  - diffusion of a topic on Twitter.

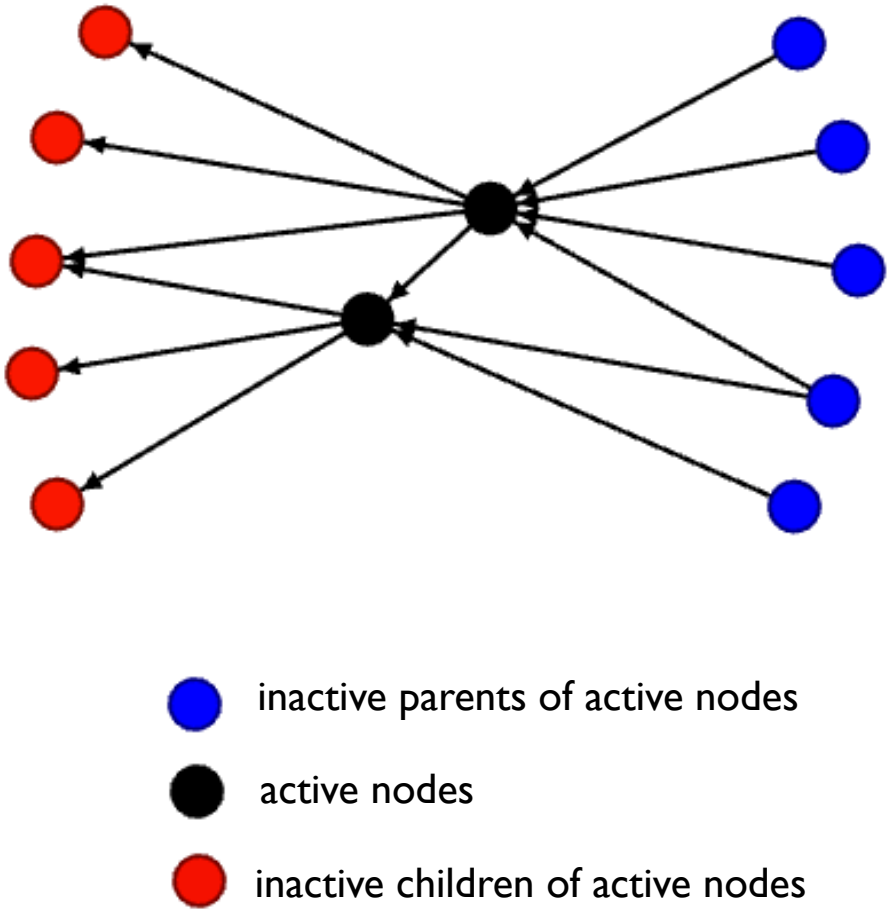
DATA COLLECTION

- Topics
  - that are **unique** and **popular** (trends)
  - that spread from **person to person** (hashtag memes/games, not events)
- Spreading mechanism
  - Retweet networks are not enough
  - Better to track who saw the topic from followees and then chose to participate (or not)

DATA COLLECTION

- 1. Collect topics.
- 2. Filter and tag Tweets.
- 3. From follow graph, get edges that Tweet authors participate in.
- 4. Filter edges such that parents come before children.
- Result: Collection of timestamped nodes and edges for each topic.

DATA COLLECTION



1. COLLECT TOPICS

- Pick a window of time.
- Find out what was trending in that window
- Record the first time it became trending (so that we can ignore it after that)

2. FILTER AND TAG TWEETS

```
-- Generate a regular expression to match tweets with any of the topics.
union_query = foreach topics generate CONCAT(CONCAT('.*\\b',name),'\\b.*');
union_query = foreach (group union_query all) generate JoinBagOr($1);

-- Filter the tweets, leaving only those with the chosen topics.
tweets = filter tweets by (text matches union_query.$0);

tweets = foreach tweets
  generate
    id,
    user_id,
    text,
    time,
    flatten(Topics(text, topics_group.$1)) as (topic, topic_start_ms,
   topic_end_ms);
```

3. EXTRACT PARTICIPATING EDGES

```
-- Get all edges in which an author is the follower
edges_l = foreach (join tweets by user_id, edges by source_id) generate
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3. EXTRACT PARTICIPATING EDGES

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  edges::source_id as source_id,
  edges::destination_id as destination_id,
```

3. EXTRACT PARTICIPATING EDGES

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-- Get all edges in which an author is the follower
edges_l = foreach (join tweets by user_id, edges by source_id) generate
  edges::source_id as source_id,
  edges::destination_id as destination_id,
  tweets::id as tweet_id,
```

3. EXTRACT PARTICIPATING EDGES

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edges_l = foreach (join tweets by user_id, edges by source_id) generate
  edges::source_id as source_id,
  edges::destination_id as destination_id,
  tweets::id as tweet_id,
  tweets::topic as topic,
```

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  edges::destination_id as destination_id,
  tweets::id as tweet_id,
  tweets::topic as topic,
  tweets::topic_start_ms as topic_start_ms,
```

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  edges::destination_id as destination_id,
  tweets::id as tweet_id,
  tweets::topic as topic,
  tweets::topic_start_ms as topic_start_ms,
  tweets::topic_end_ms as topic_end_ms,
  tweets::time as source_tweet_time;
```

3. EXTRACT PARTICIPATING EDGES

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-- Get all edges in which an author is the follower
edges_l = foreach (join tweets by user_id, edges by source_id) generate
  edges::source_id as source_id,
  edges::destination_id as destination_id,
  tweets::id as tweet_id,
  tweets::topic as topic,
  tweets::topic_start_ms as topic_start_ms,
  tweets::topic_end_ms as topic_end_ms,
  tweets::time as source_tweet_time;

-- Get all edges in which an author is the followee
edges_r = foreach (join tweets by user_id, edges by destination_id) generate
  edges::source_id as source_id,
  edges::destination_id as destination_id,
  tweets::id as tweet_id,
  tweets::topic as topic,
  tweets::topic_start_ms as topic_start_ms,
  tweets::topic_end_ms as topic_end_ms,
  tweets::time as destination_tweet_time;
```

3. EXTRACT PARTICIPATING EDGES

user_id	…
1	…
2	…
3	…
4	…

source	destination
1	29
50	2
3	1
23	56

source	destination	
1	29	…
3	1	…

3. EXTRACT PARTICIPATING EDGES

user_id	…
1	…
2	…
3	…
4	…

source	destination
1	29
50	2
3	1
23	56

source	destination	
50	2	…
3	1	…

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
```

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
    source_id,
```

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edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
```

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    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
```

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  (edges_r::destination_id IS NULL ? edges_l::destination_id :
   edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
   edges_r::topic_start) as topic_start,
```

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
   source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
   edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
   edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
   topic_end,
```

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
    edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
    topic_end,
  edges_l::source_tweet_id as source_tweet_id,
```

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
    edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
    topic_end,
  edges_l::source_tweet_id as source_tweet_id,
  edges_r::destination_tweet_id as destination_tweet_id,
```

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edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
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    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
    edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
    topic_end,
  edges_l::source_tweet_id as source_tweet_id,
  edges_r::destination_tweet_id as destination_tweet_id,
  edges_l::source_tweet_time as source_tweet_time,
```

3. EXTRACT PARTICIPATING EDGES

```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
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    source_id,
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  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
    edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
    topic_end,
  edges_l::source_tweet_id as source_tweet_id,
  edges_r::destination_tweet_id as destination_tweet_id,
  edges_l::source_tweet_time as source_tweet_time,
  edges_r::destination_tweet_time as destination_tweet_time,
```

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```
edges = foreach (join edges_l by (source_id, destination_id, topic) FULL,
    edges_r by (source_id, destination_id, topic)) generate
  (edges_r::source_id IS NULL ? edges_l::source_id : edges_r::source_id) as
    source_id,
  (edges_r::destination_id IS NULL ? edges_l::destination_id :
    edges_r::destination_id) as destination_id,
  (edges_r::topic IS NULL ? edges_l::topic : edges_r::topic) as topic,
  (edges_r::topic_start IS NULL ? edges_l::topic_start :
    edges_r::topic_start) as topic_start,
  (edges_r::topic_end IS NULL ? edges_l::topic_end : edges_r::topic_end) as
    topic_end,
  edges_l::source_tweet_id as source_tweet_id,
  edges_r::destination_tweet_id as destination_tweet_id,
  edges_l::source_tweet_time as source_tweet_time,
  edges_r::destination_tweet_time as destination_tweet_time,
  (edges_r::source_id IS NULL ? 1 : (edges_l::source_id IS NULL ? -1 : 0))
    as type;
```

3. EXTRACT PARTICIPATING EDGES

source	destination	
1	29	…
3	1	…

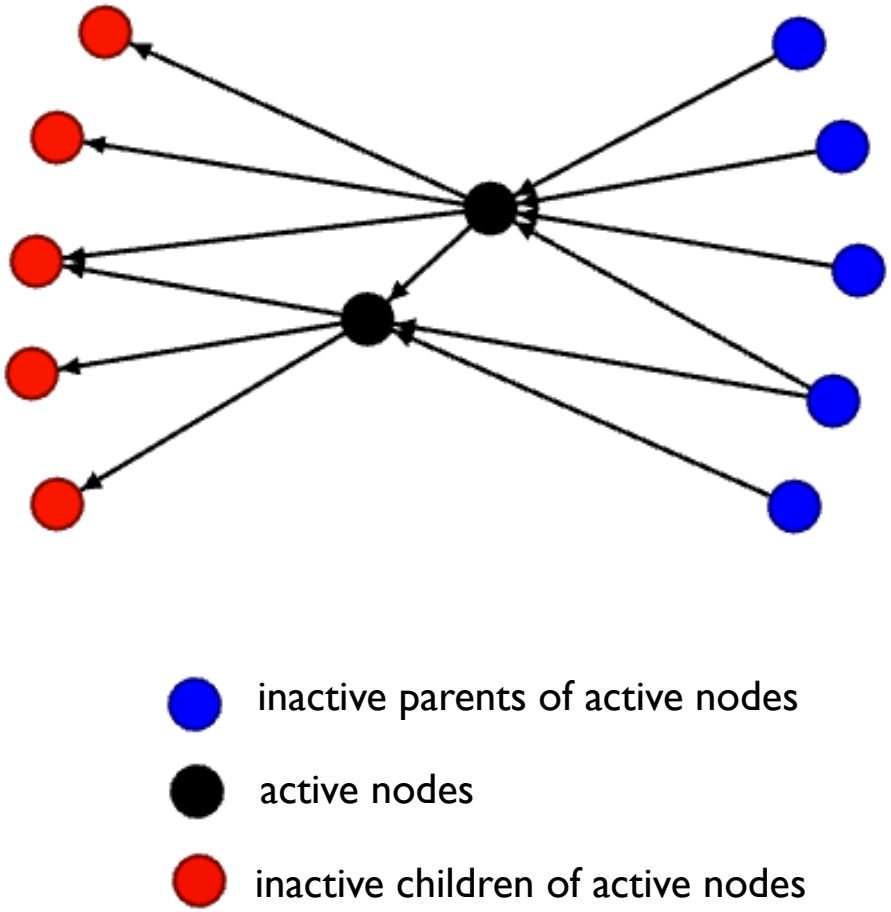
source	destination	
50	2	…
3	1	…

source	destination	type	…
50	2	-1	…
3	1	0	…
1	29	1	…

4. FILTER EDGES BY TIME

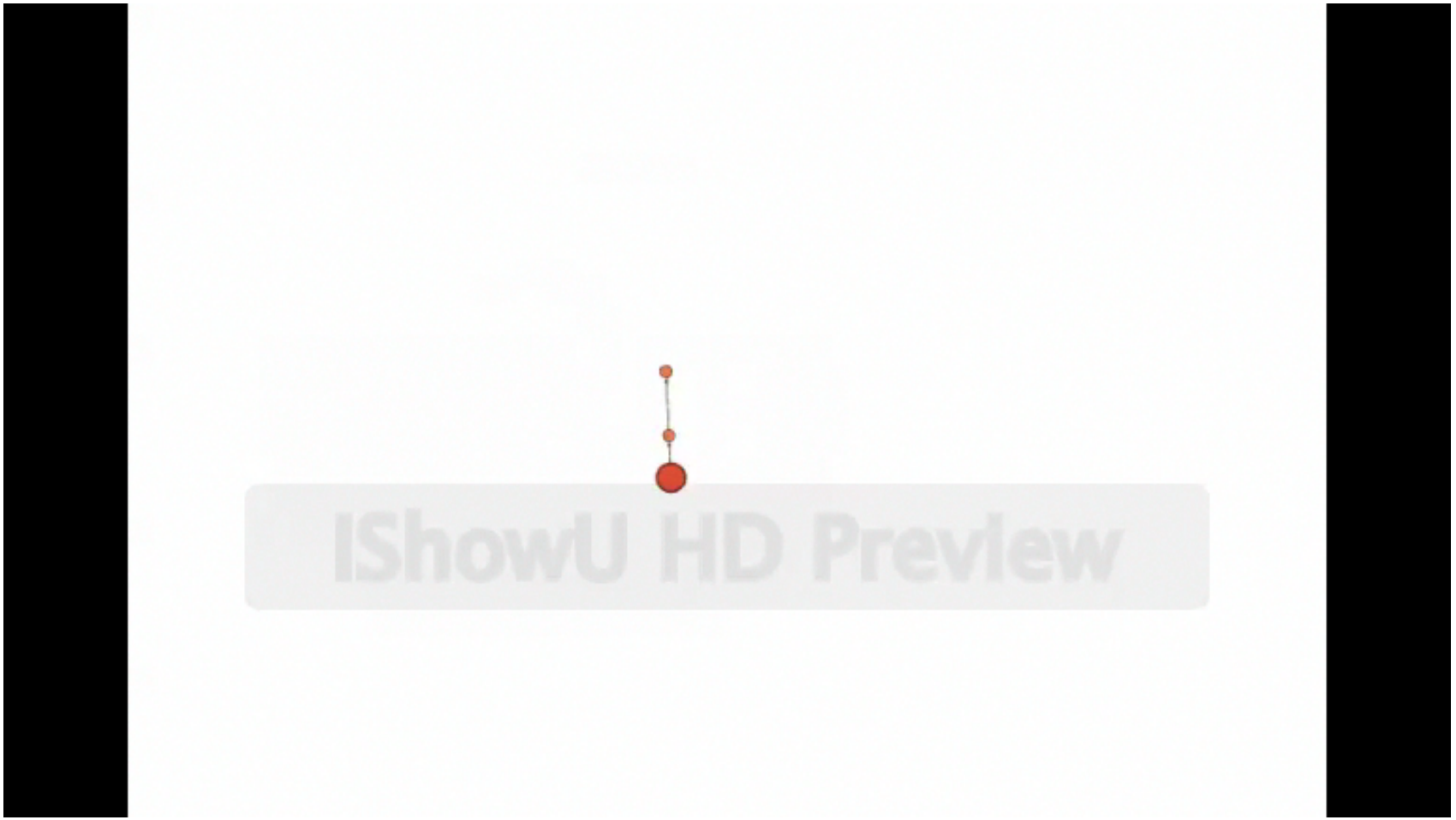
```
edges = filter edges by (source_tweet_time < topic_start);
```

DATA COLLECTION



#DebateLinesForRomney

#BackStreetCruiseAlright



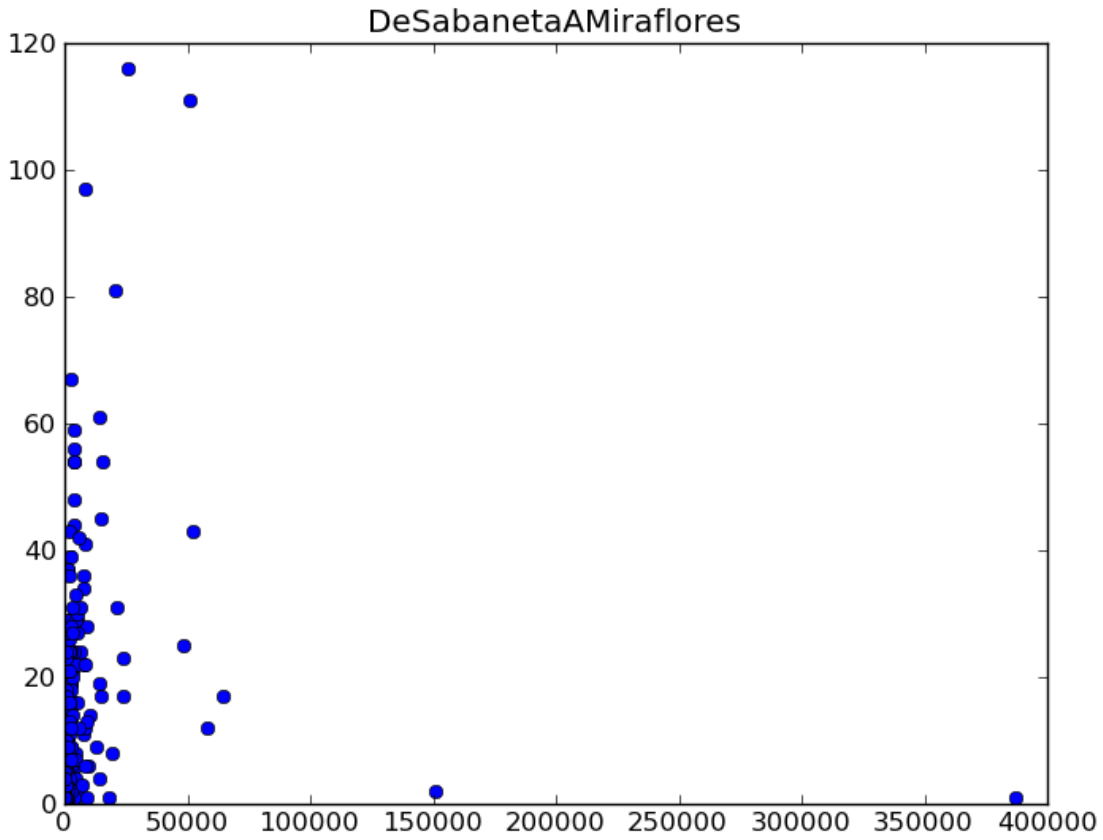
#GalinhaPintadinhaHumilhaLuaBlanco

#YouBelongOnJerrySpringer (up to 2 parents)

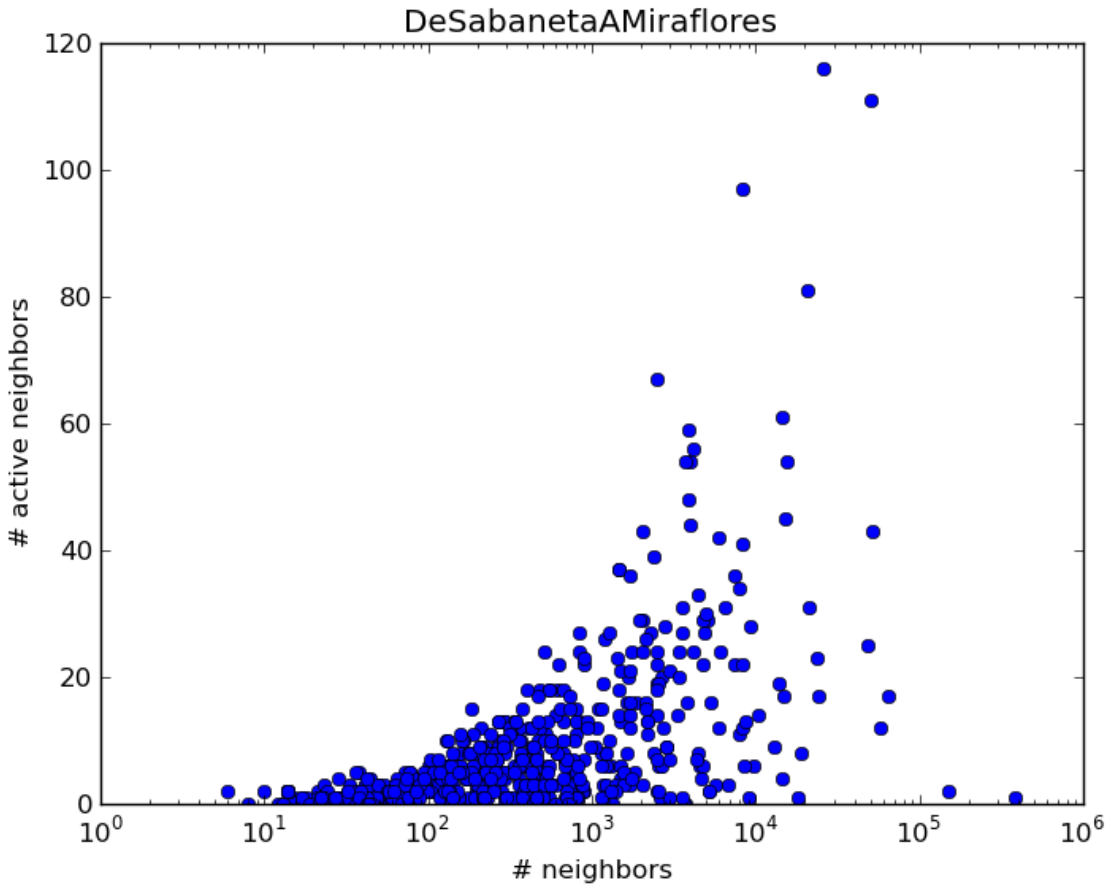
#TurkishDirectionersLovesHarryStayStrong

#AustraliaNeedsBelieveTourDates

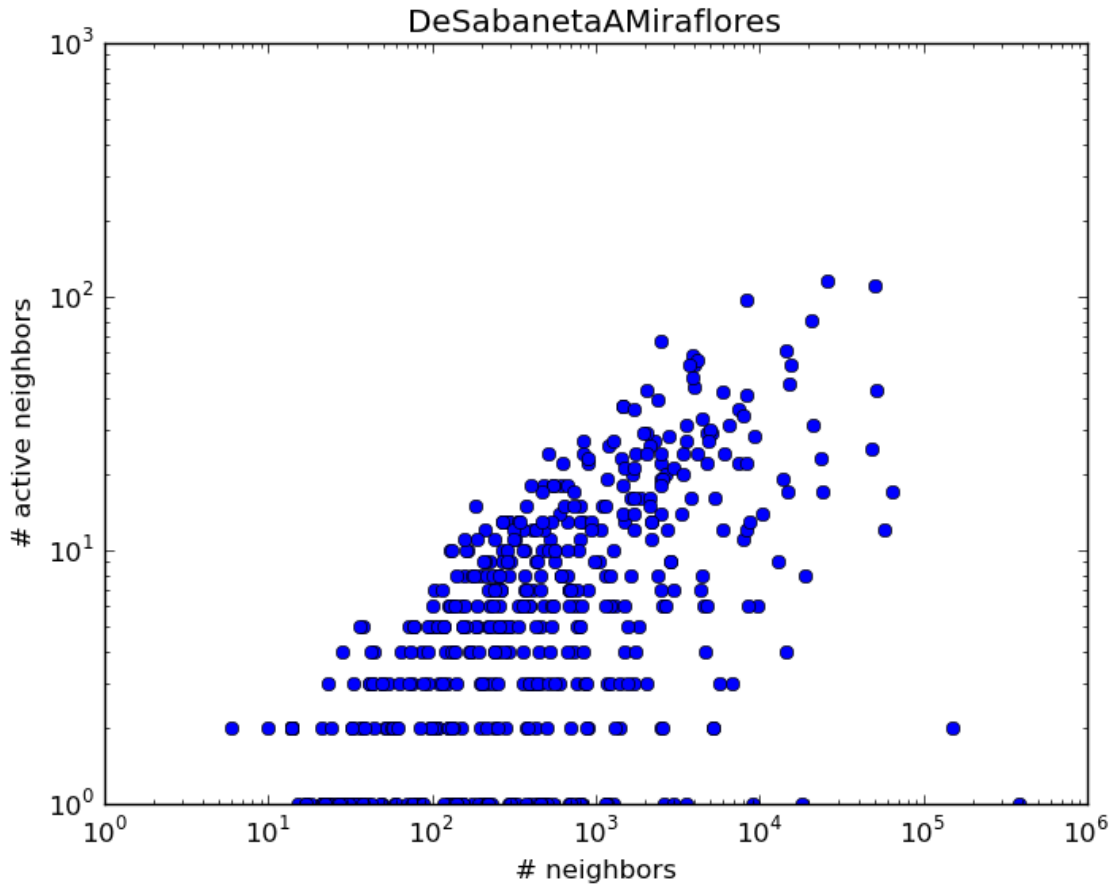
linear-linear

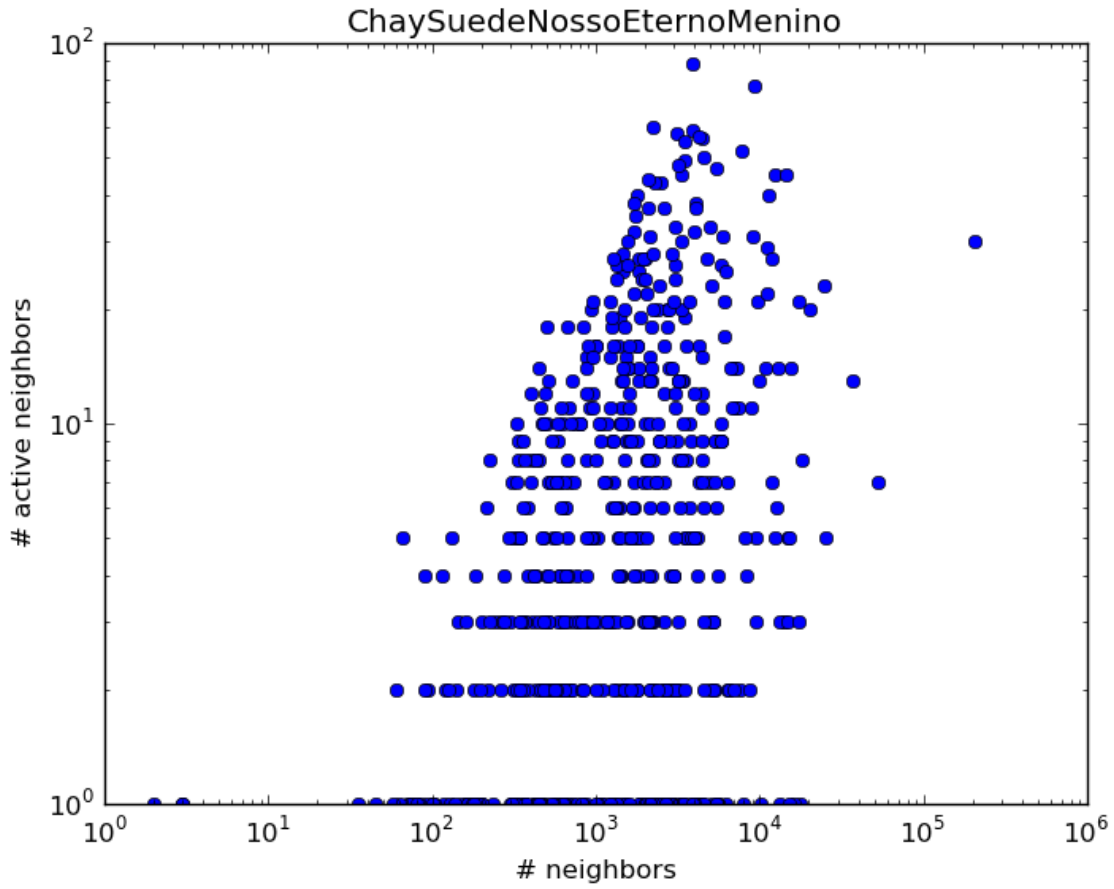


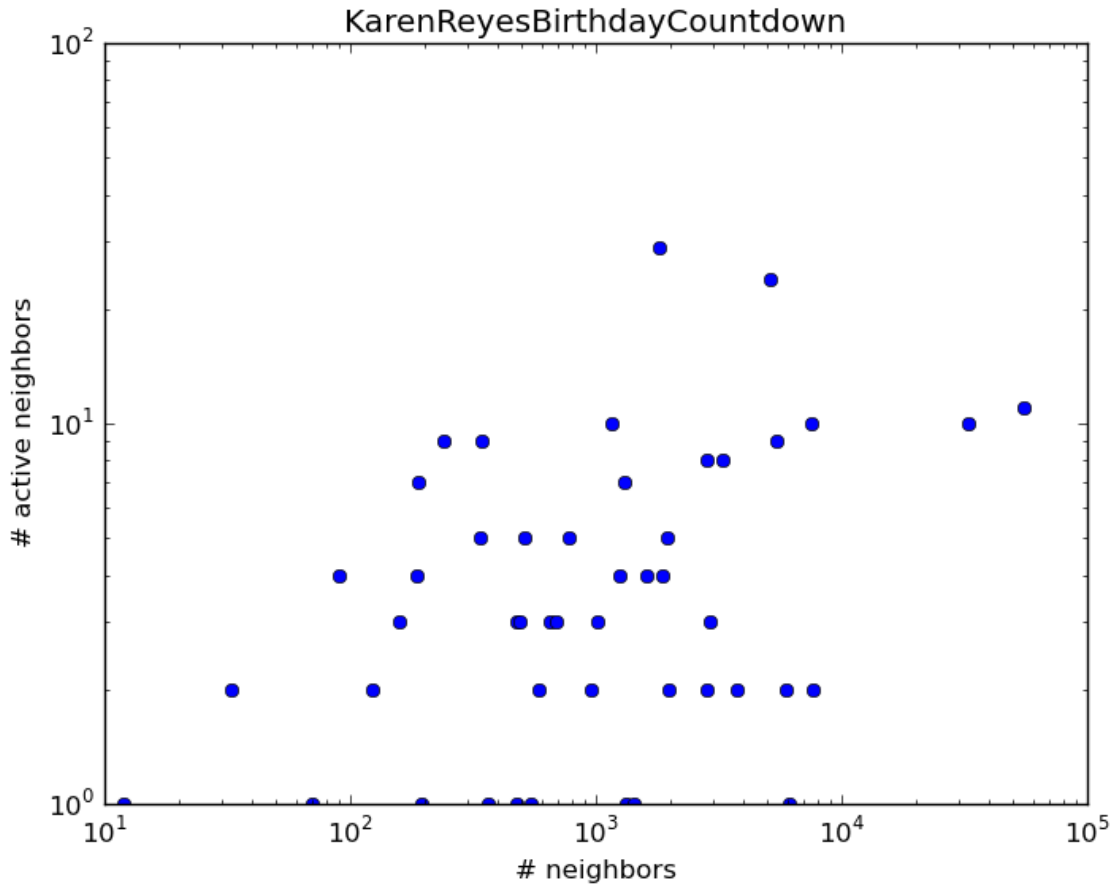
log-linear

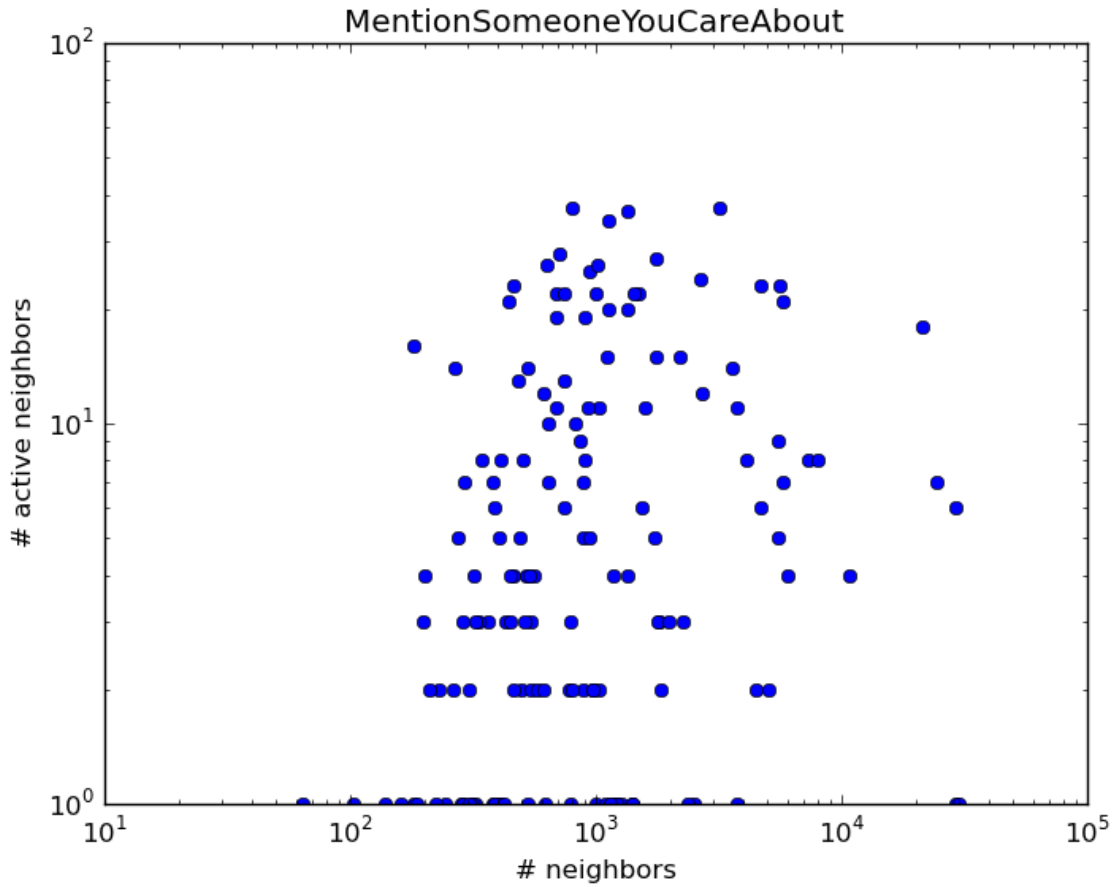

DeSabanetaAMiraflores
active neighbors
neighbors
0
20
40
60
80
100
120
10^0
10^1
10^2
10^3
10^4
10^5
10^6

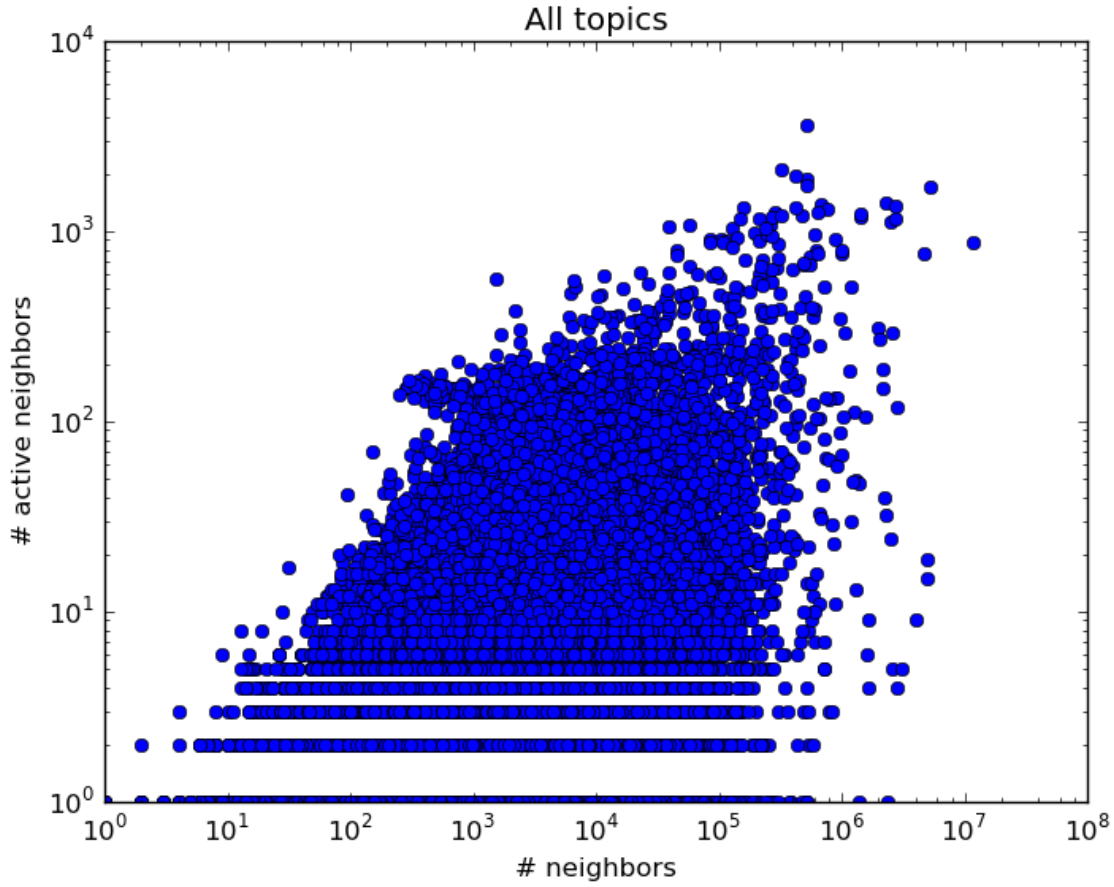
log-log

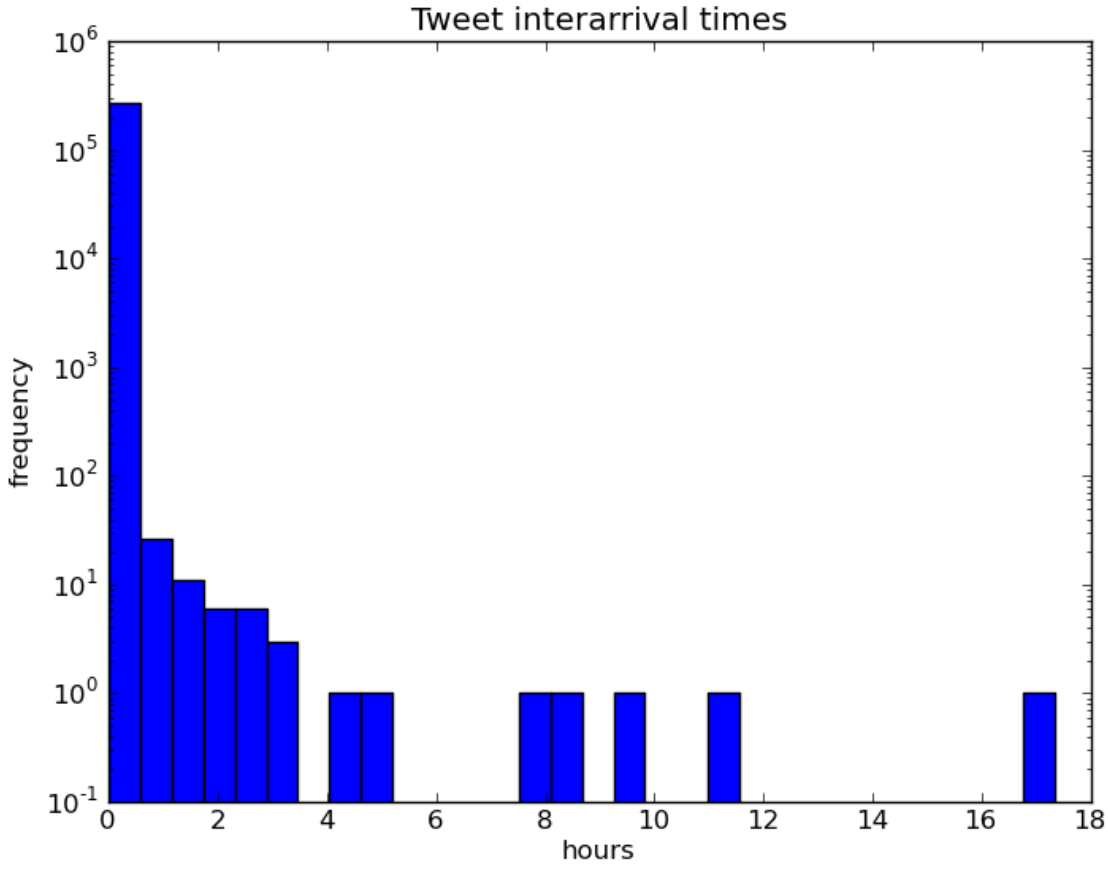

DeSabanetaAMiraflores
active neighbors
neighbors
10^0
10^1
10^2
10^3
10^4
10^5
10^6


ChaySuedeNossoEternoMenino
active neighbors
neighbors
10^0
10^1
10^2
10^3
10^4
10^5
10^6


KarenReyesBirthdayCountdown
active neighbors
neighbors
10^0
10^1
10^2
10^1
10^2
10^3
10^4
10^5


MentionSomeoneYouCareAbout
active neighbors
neighbors
10^0
10^1
10^2
10^1
10^2
10^3
10^4
10^5


All topics
active neighbors
neighbors
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8


Tweet interarrival times
frequency
hours
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
2
4
6
8
10
12
14
16
18

EXPERIMENTAL DIFFICULTIES

- Difficulty of choosing **topics**
  - Do topics stop spreading or start trending?
  - Look at rate of growth: is it slowing down or speeding up?
  - Look at candidates for trends that never become trends.
- Person-to-person vs. **exogenous** influence
  - How else is the topic being spread?
- Real users, followings are **not all the same**
  - Could estimate each person's individual threshold

CONCLUSIONS

- Clusters are an obstacle to widespread diffusion (in theory)
- Tracking information spreading in a real network is non-trivial
- Simple models can be useful conceptually but tricky to apply to real data.

FUTURE WORK

- Better selection of topics
- Per user model
- More of graph around active nodes to study effect of clustering.

QUESTIONS?